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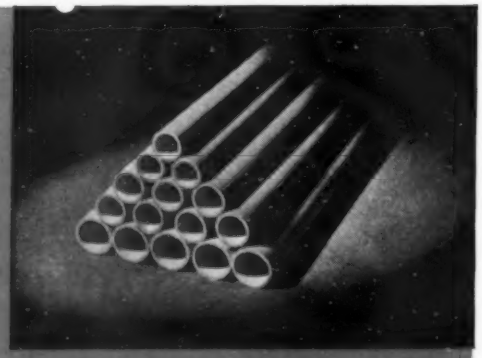
MULLITE
COMBUSTION
TUBES



These special refractory tubes are a new development for temperatures above the limit of VITREOSIL (1050° C.) and below the range of the more refractory tubes of FUSED ALUMINA, MAGNESIA, etc.

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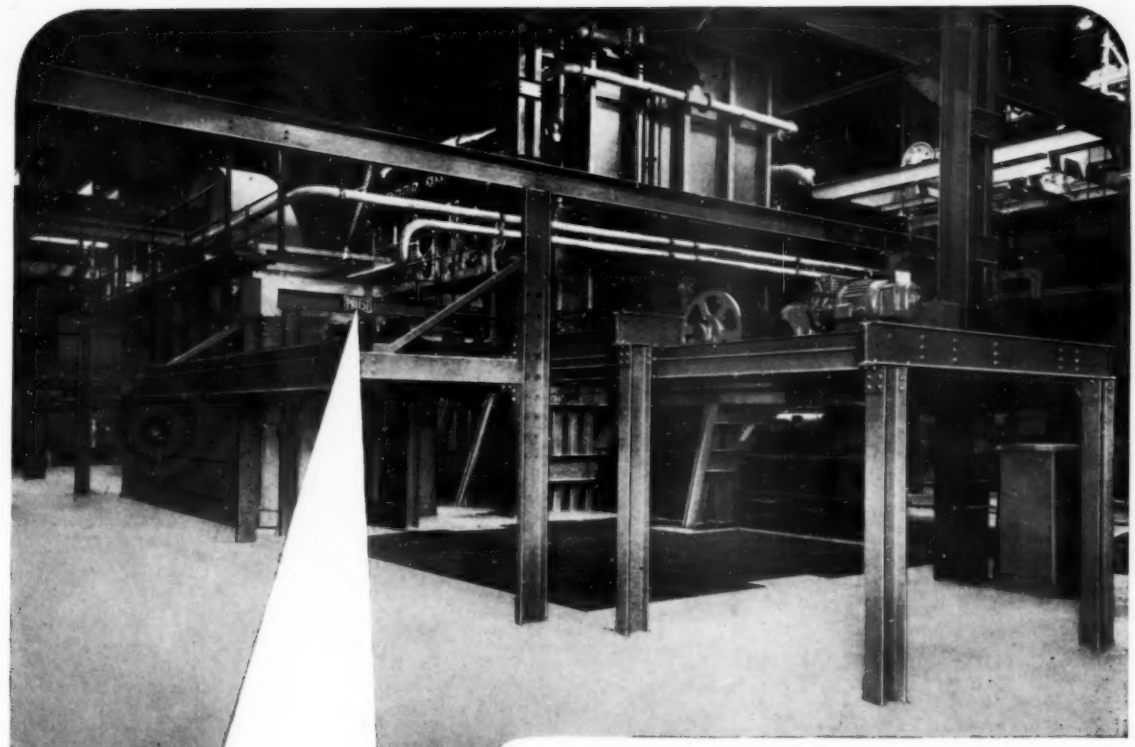

PRIEST

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All Priest Furnaces are special jobs, designed expressly for their duty. They thus afford maximum output, with great convenience of operation, and high fuel efficiencies.

The illustration shows a complete solution treatment plant for aluminium and alloy sheets, for the British Aluminium Company, Ltd. Clean hot air circulated at high velocity is used, with quench tank below, hoist and quench mechanism, loading cranes, conveyor and dryer. Capacity 1 ton of sheets per hour.

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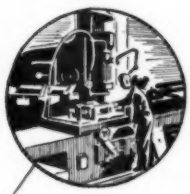


DETAIL DESIGN

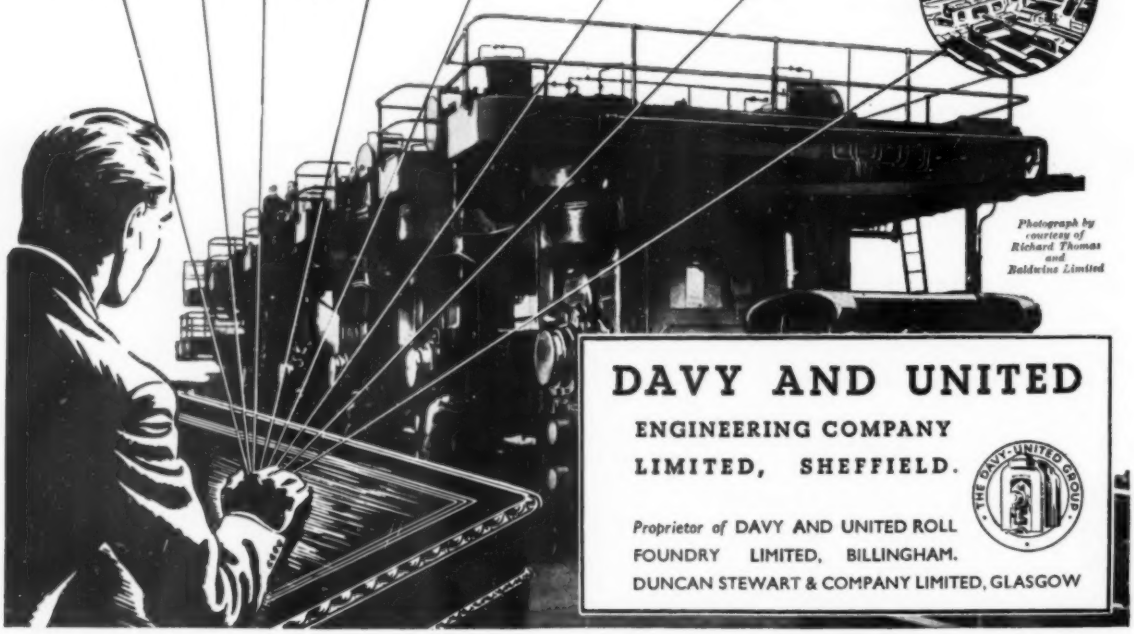
SHOP ERECTION

LAYOUT

ASSEMBLY ON SITE

VICTORY nowadays goes as frequently to the rational as to the strong. In the purely military field, for example, success is now more than ever a matter of timing and supply, of getting the right forces to the right place at the right time; it presupposes in fact a campaign planned carefully in advance and fought to a pre-drawn pattern. That's the way we like to approach a major operation of another kind, the building of large rolling mill plant. The mill below represents about 3,000 tons of machinery: its parts are numbered in thousands; it can take as long as two years to design and build. Contracts like that call for planning in the military vein — first on a broad strategic basis covering the operation as a whole and secondly on closer tactical lines by which each of the works departments named in the broader plan can achieve the objectives set for them.

Any strategic plan needs room for manœuvre—we get that by having in our Sheffield and Glasgow works the largest block of manufacturing capacity in Britain engaged in this class of engineering. Tactical operations need co-ordination — we get that by personal generalship, marshalling an organisation which year by year is bringing mills like this one into the service of industry.



Photograph by courtesy of Richard Thomas and Baldwins Limited

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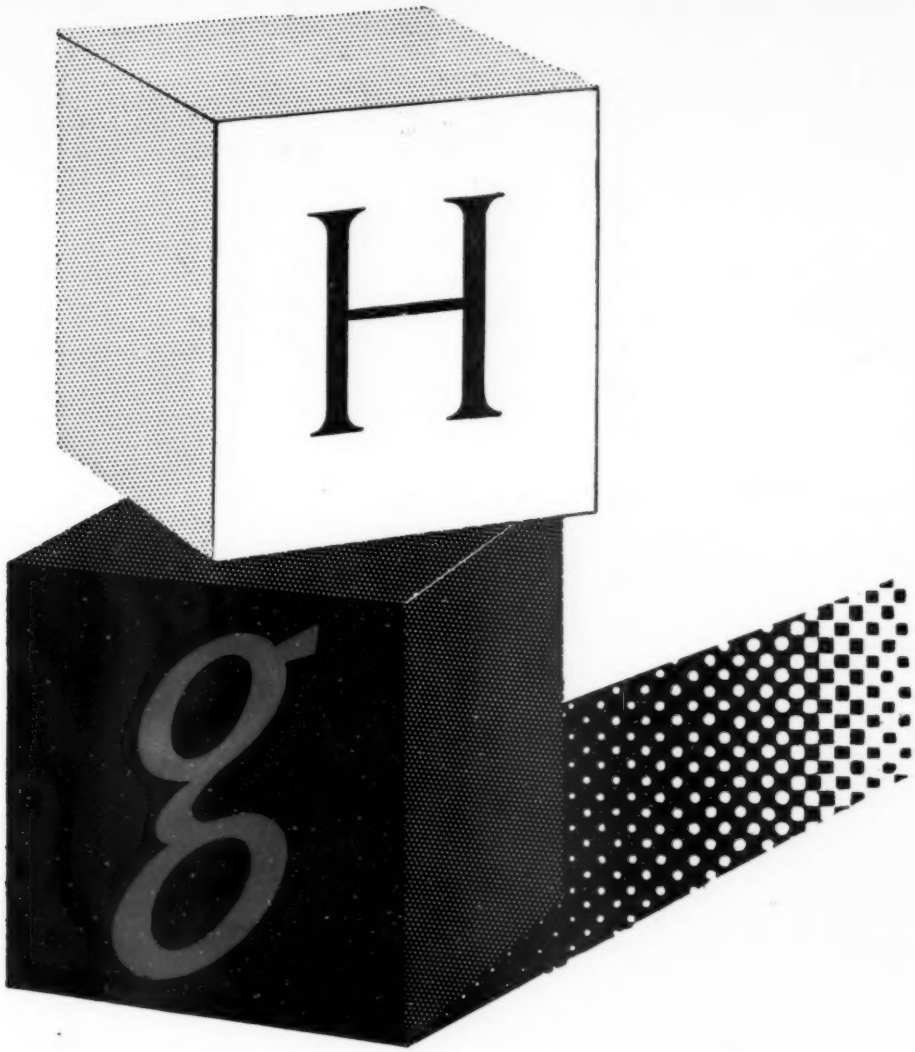

H comes after G in the alphabet and Hiduminium certainly came after gravity. Indeed, it was only 21 years ago that Hiduminium really got to grips with the age old problem of how to achieve lightness without sacrificing strength. Now, manufacturers in practically every industry have at hand a range of materials which are light and strong, which resist corrosion, reduce stress and running costs, are non-toxic, easily worked and lend themselves to a number of attractive finishes. No wonder more and more people prefer to

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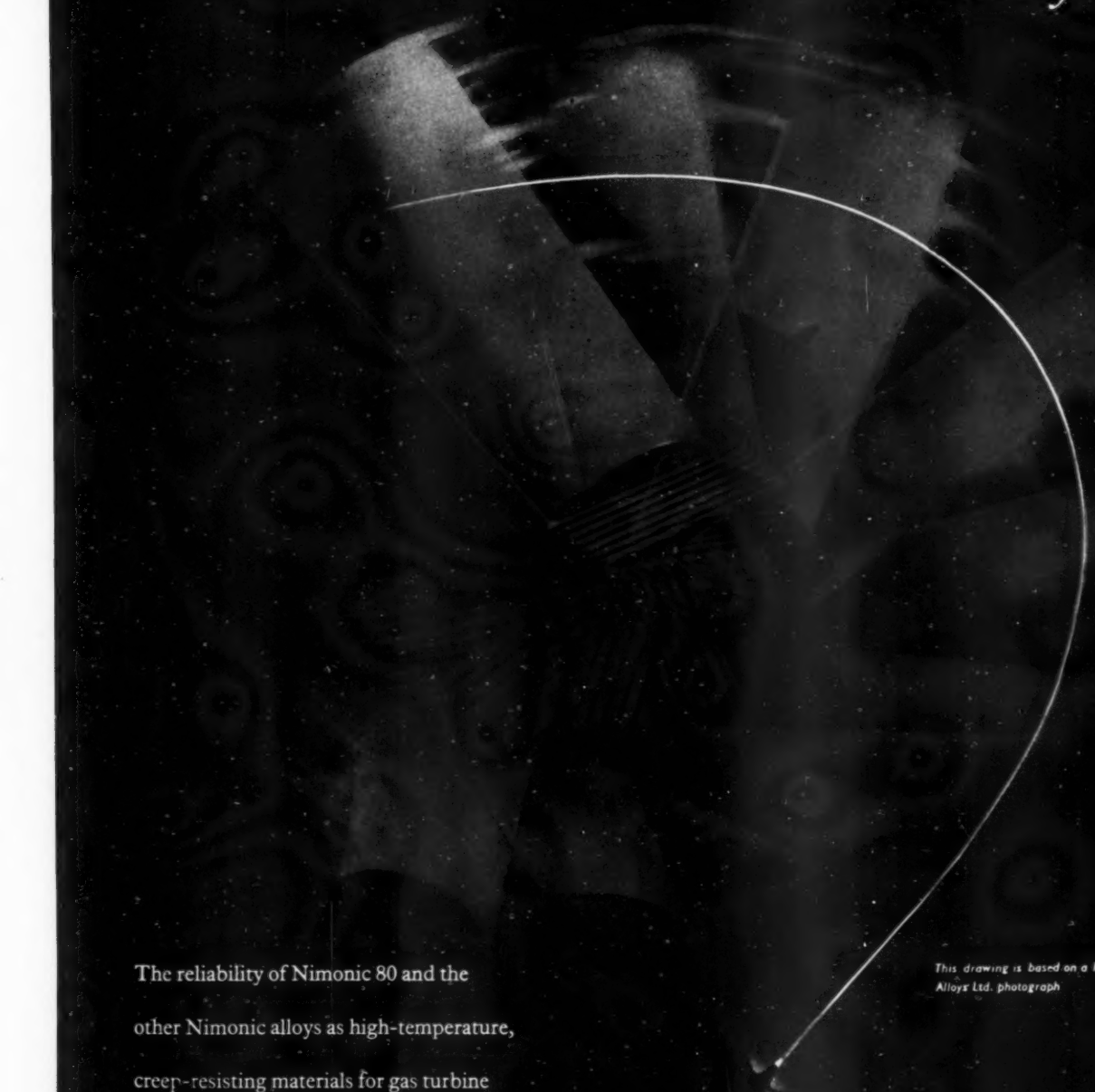

This drawing is based on a High Duty Alloys Ltd. photograph

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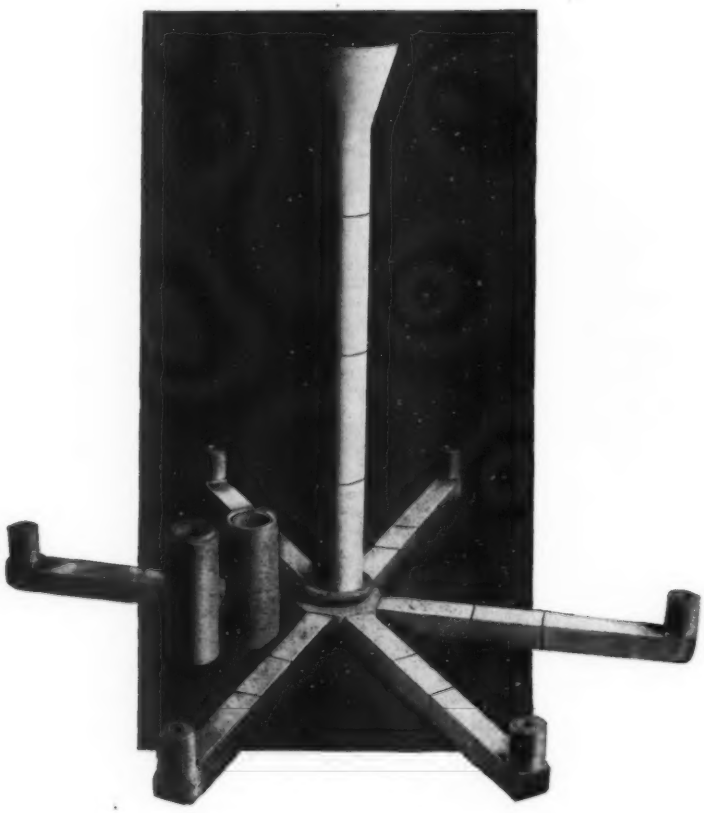

REFRACTORIES

The illustration shows a typical 6-way uphill casting assembly as used for casting nests of large ingots in a modern Steel Works, shorn of its outer casings.

The excellent jointing, which is a feature of our bricks, can be seen at all points, and modern methods of technical control are used in production to assure the maintenance of this high standard.

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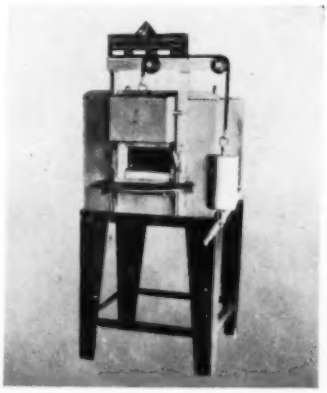

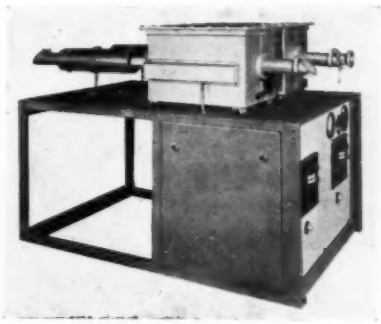

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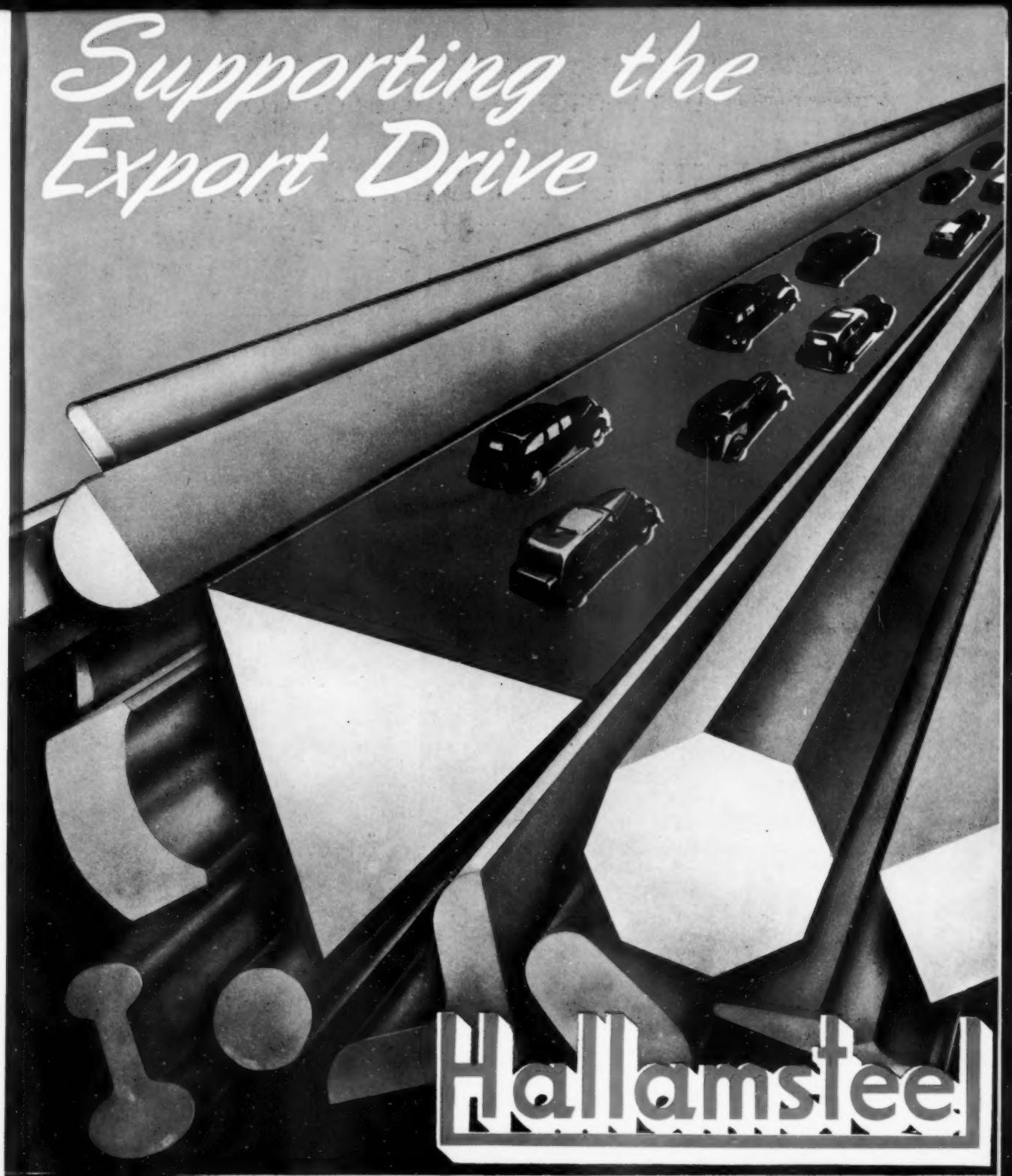

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Primarily for elevated temperature work the new "Elektron" Alloy Z.R.E.1 Magnesium-Zinc-Zirconium-Rare Earth can be supplied "As Cast" or Heat-Treated to suit specific applications, and has the following attractive properties:— Practically creep resistant at 200°C. Complete freedom from micro-porosity. Full details are available on request.

● **Sterling Metals** *are the pioneers in this country of "Elektron" Magnesium Alloy castings, and are the largest producers of magnesium castings in the world. They lead the field in the achievement of intricate and highest quality castings*

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Victor Bricks are made in three densities, 30, 40 and 48 lbs. per cubic ft. Full physical characteristics and samples will be submitted on request.

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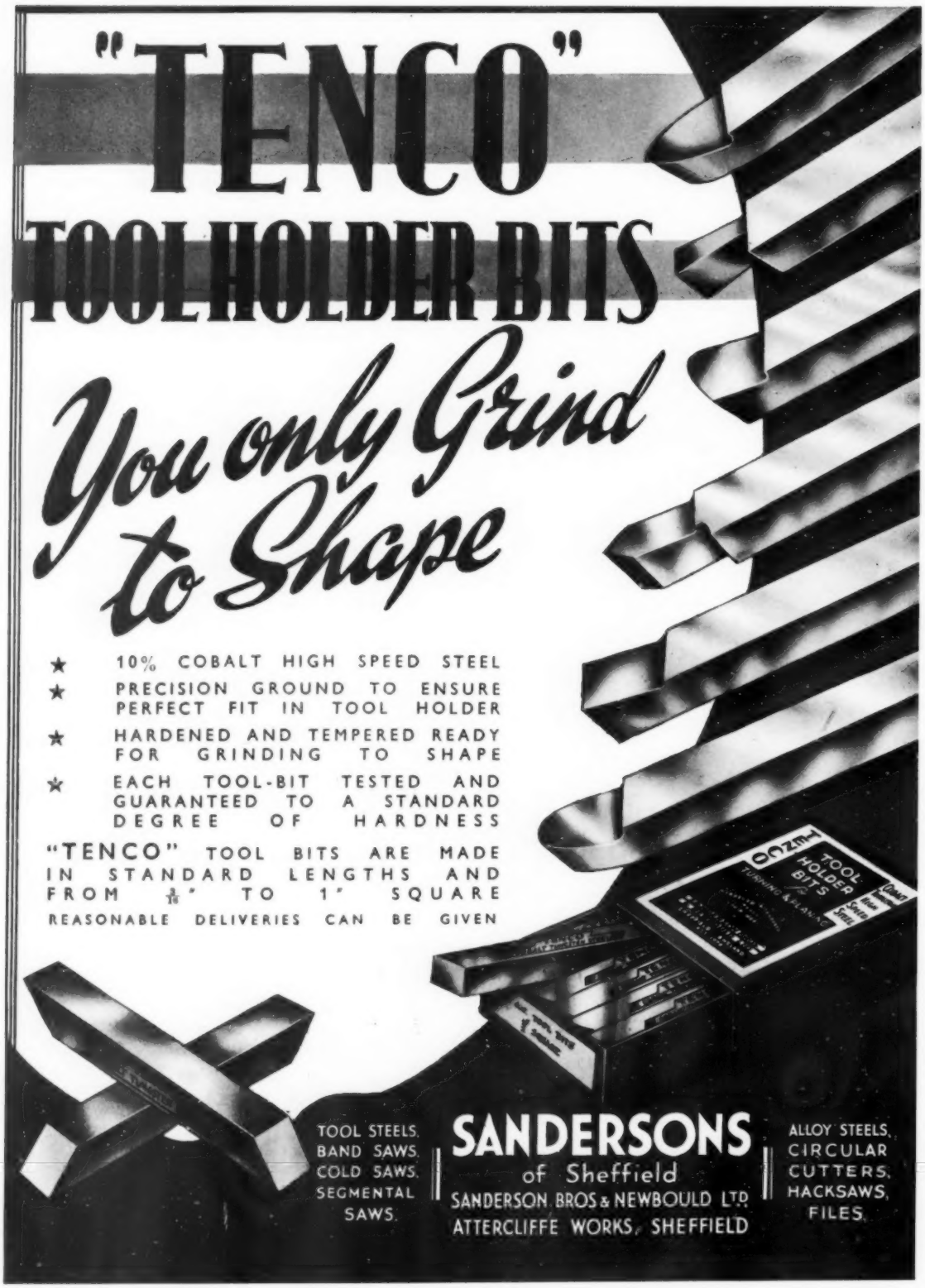

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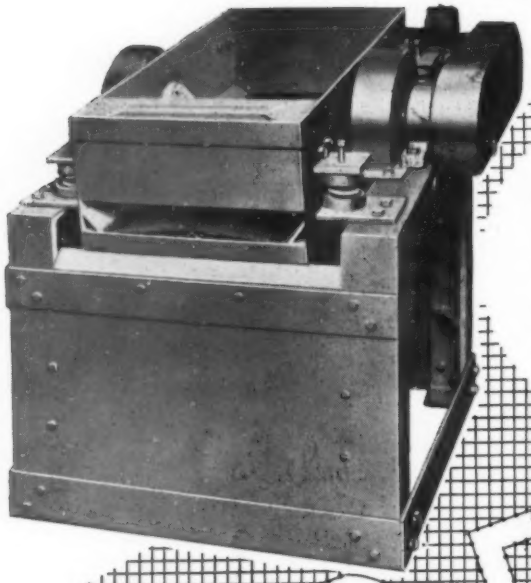

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A robust, practical job for all grading and screening purposes.

Single, double or treble decks in all sizes.

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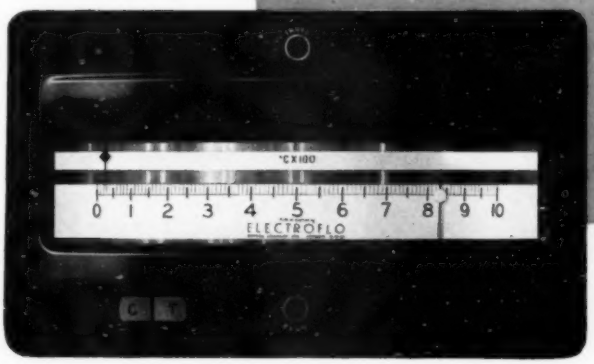

Model No. 1560, Electronic 10" Scale Indicating Control Pyrometer.

ELECTROFLO
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Mechanical —Series 154 **Electronic** —Series 156

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for LABORATORIES
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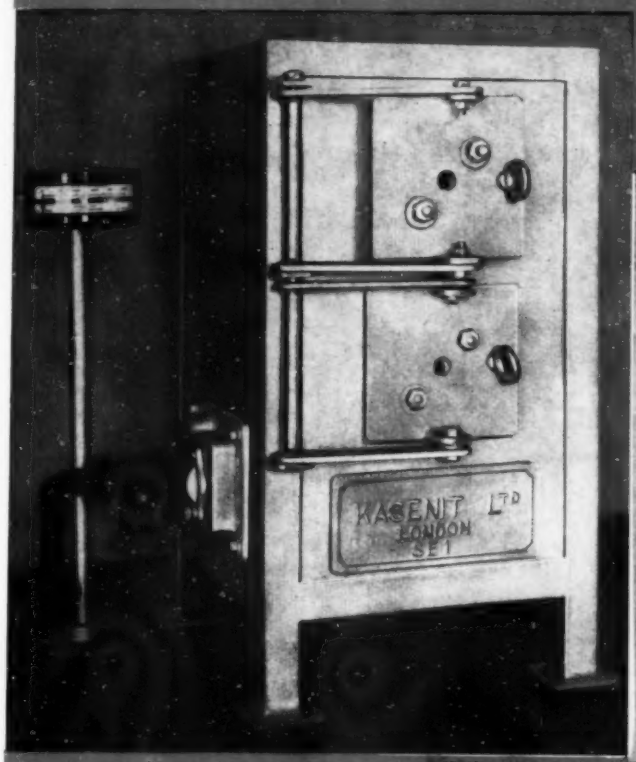

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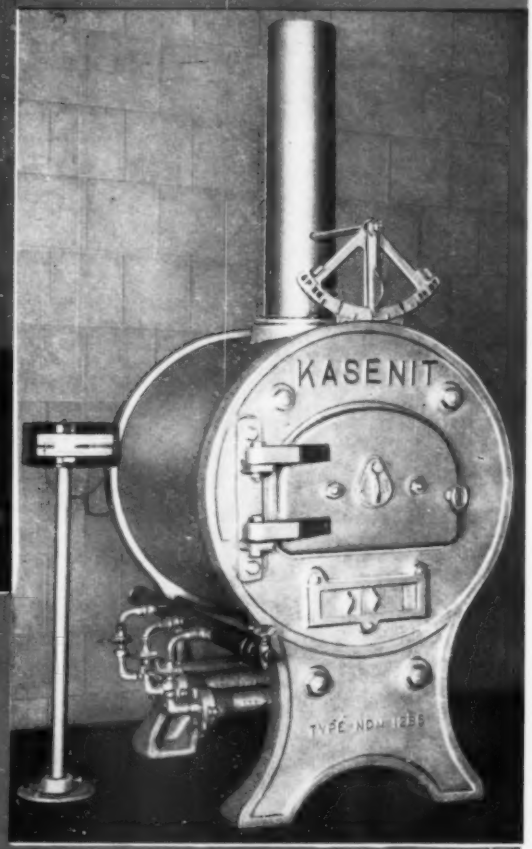
Size of each chamber 4½" wide × 4½" high × 7½" long
A Temperature up to 1300°C. in 20 mins.



BENCH TYPE GAS FIRED MUFFLE FURNACE IN TWO SIZES: 5" wide × 3" high × 9" long } TEMP. 1000°C.
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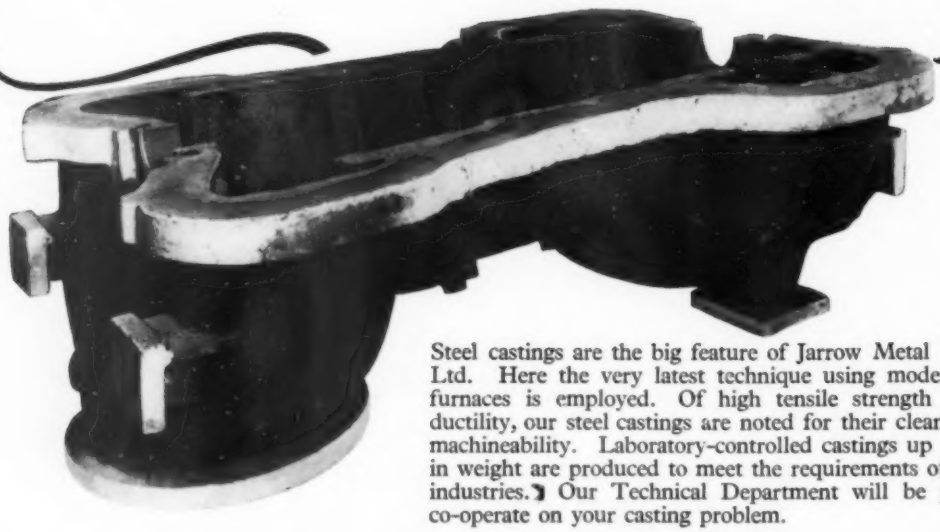

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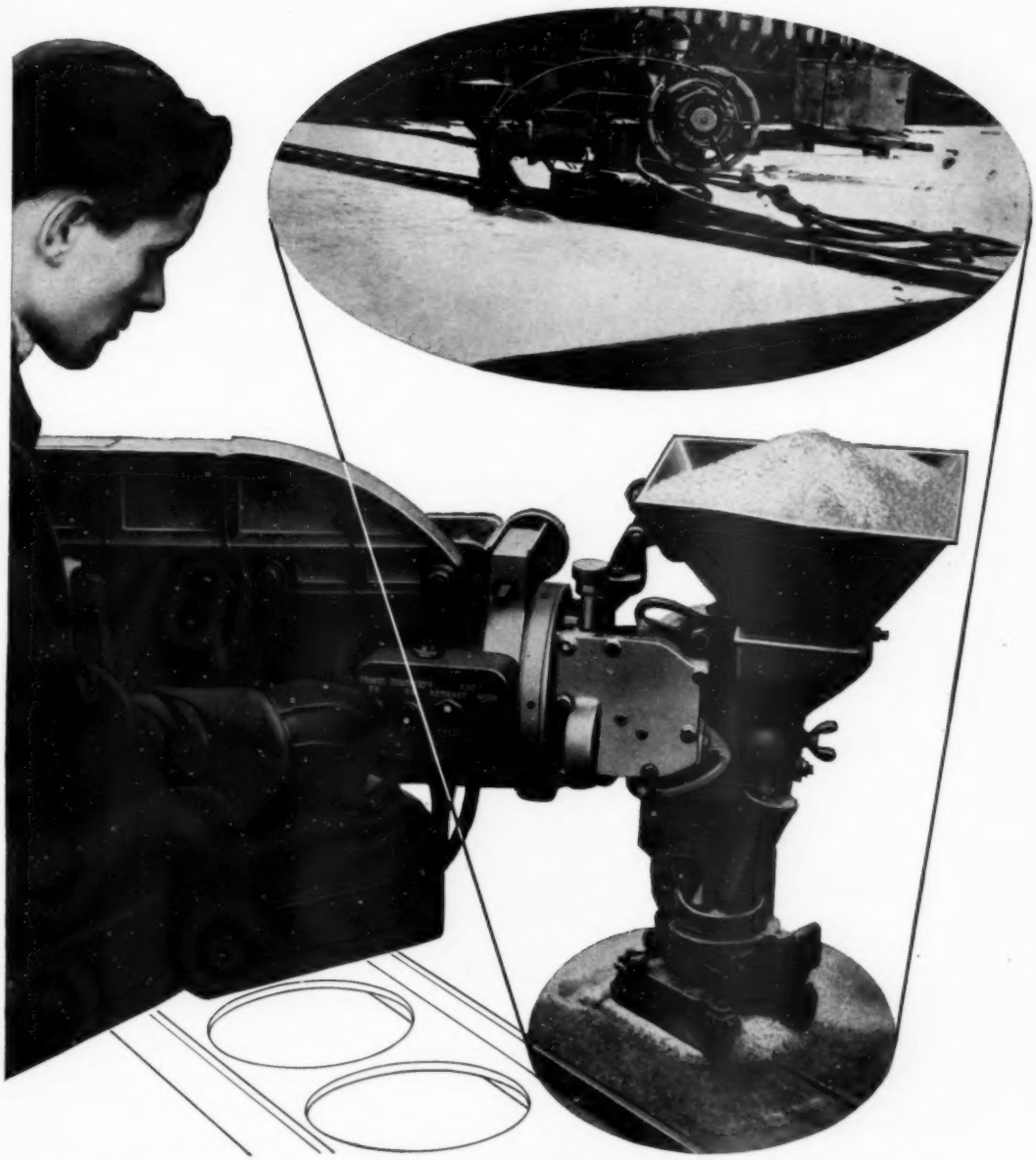

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Of all methods of making butt, fillet and plug welds in mild steel plate, Unionmelt Automatic Electric Welding is the fastest—it does the job ten to twenty times faster (according to conditions) than by hand.

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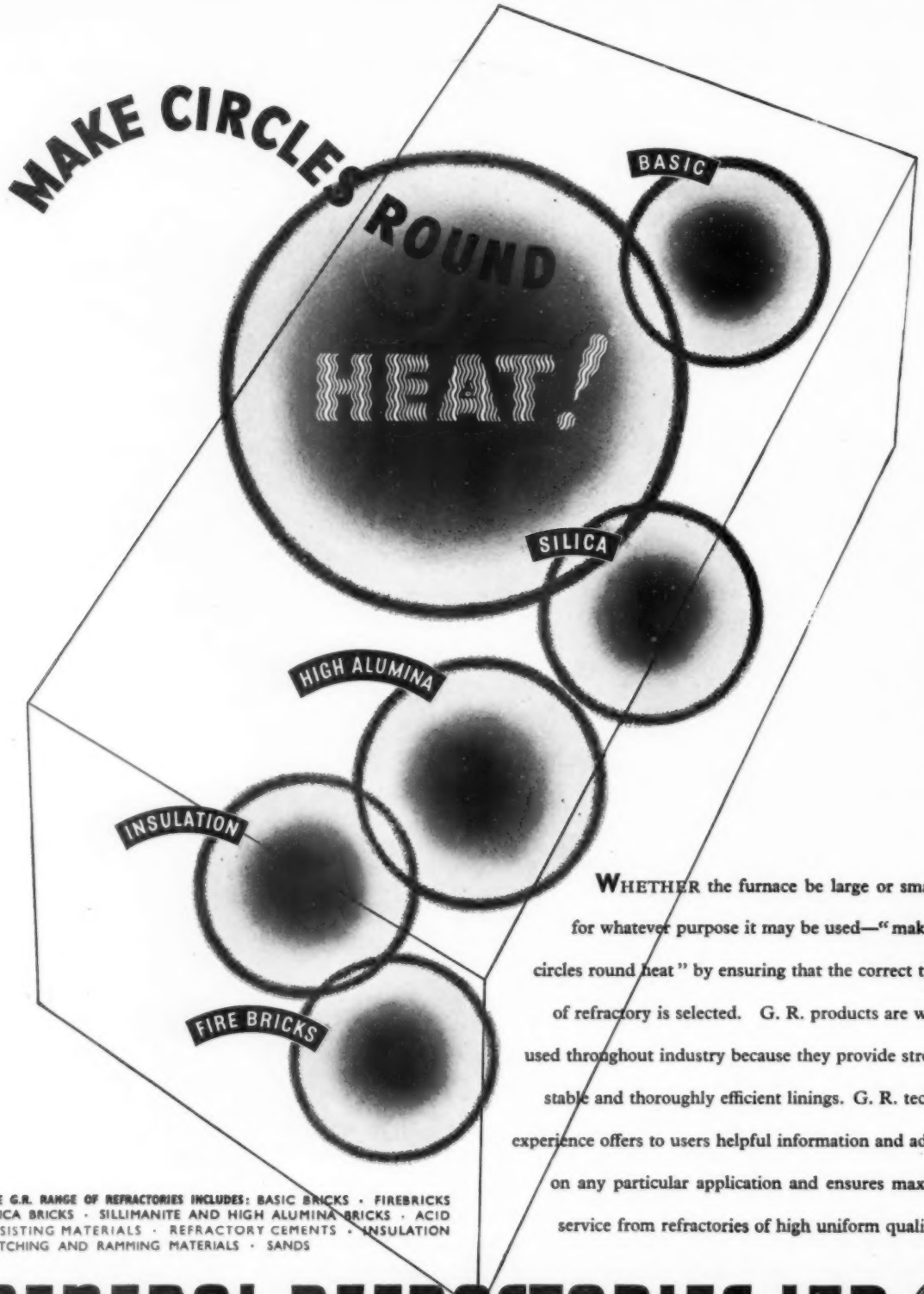

WHETHER the furnace be large or small and for whatever purpose it may be used—"make circles round heat" by ensuring that the correct type of refractory is selected. G. R. products are widely used throughout industry because they provide strong, stable and thoroughly efficient linings. G. R. technical experience offers to users helpful information and advice on any particular application and ensures maximum service from refractories of high uniform quality.

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The keynote of the late Gothic field armour was elegance, but that of the suits constructed for the violent collisions of the tilt yard was unyielding strength. The object of the tilter was to shatter his lance on his opponent and so unseat him; as these suits weighed nearly 100 lb., a fall was not without danger.

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A present day analogy to the high degree of protection offered by the tilt suit, is the protective hard case of considerable depth and uniform hardness which can be applied to steel by

'CASSEL'
'RAPIDEEP' BATHS

For details of the 'CASSEL' HEAT-TREATMENT SERVICE apply to:—

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TWIN SALT BATH FURNACE

Brayshaw Twin Salt Bath Furnaces are designed in accordance with the most up-to-date principles.

Both pots are interchangeable ; the working pot in the main heating chamber contains the fusible salt, whilst the second pot, heated by the waste products of combustion, serves for preheating the work, and at the same time serves as a standby in case the high temperature pot fails.

A removable hood encloses both pots. A motor-driven automatic stirrer is fitted. Further particulars and sizes on application.

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greater freedom — greater reliability !

NEW "Elektron" magnesium-zirconium **wrought** alloys ZW3 and ZW2 possess unique advantages in mechanical strength and ease of fabrication: they open up new possibilities for designers in lightweight/high-strength construction from **sheet, tube and solid extrusions.** Typical test figures are:—

	0.1% P.S. t.s.i.	U.T.S. t.s.i.	*Elongation* % on 2"
ZW3 sheet . .	11–14	17–20	8–18 (or 4 T cold bend in thinner gauges)
ZW3 solid extrusions (high strength) . .	17–21	23–26	8–14
ZW3 solid extrusions (medium strength)	14–17	20–23	12–25
ZW2 tube . .	11–15	17–22	3–8

Fatigue endurance value of ZW3 solid extrusions (high strength) (50×10^6 reversals) unnotched . . 9.5 t.s.i.
notched . . 5.75 „

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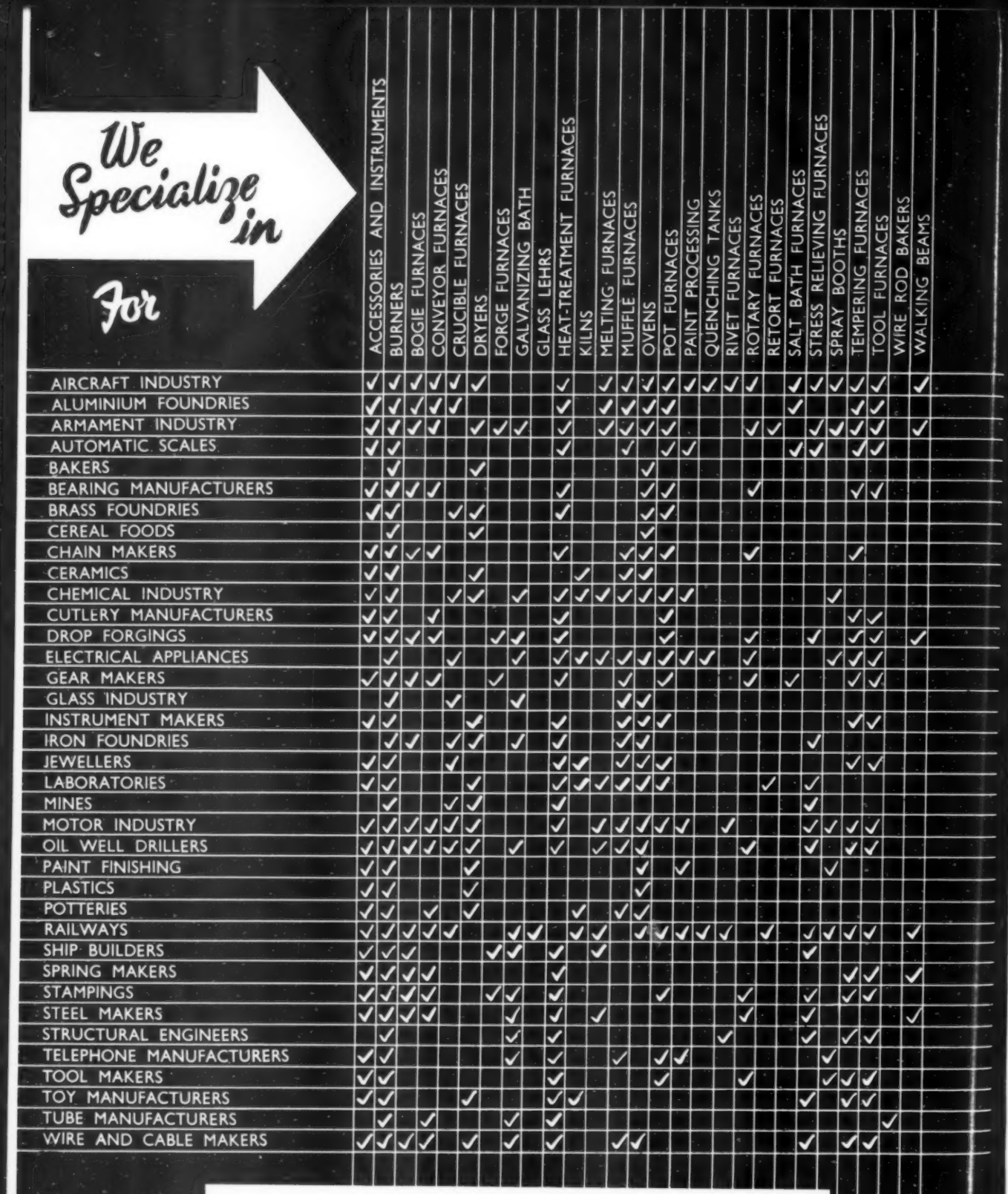

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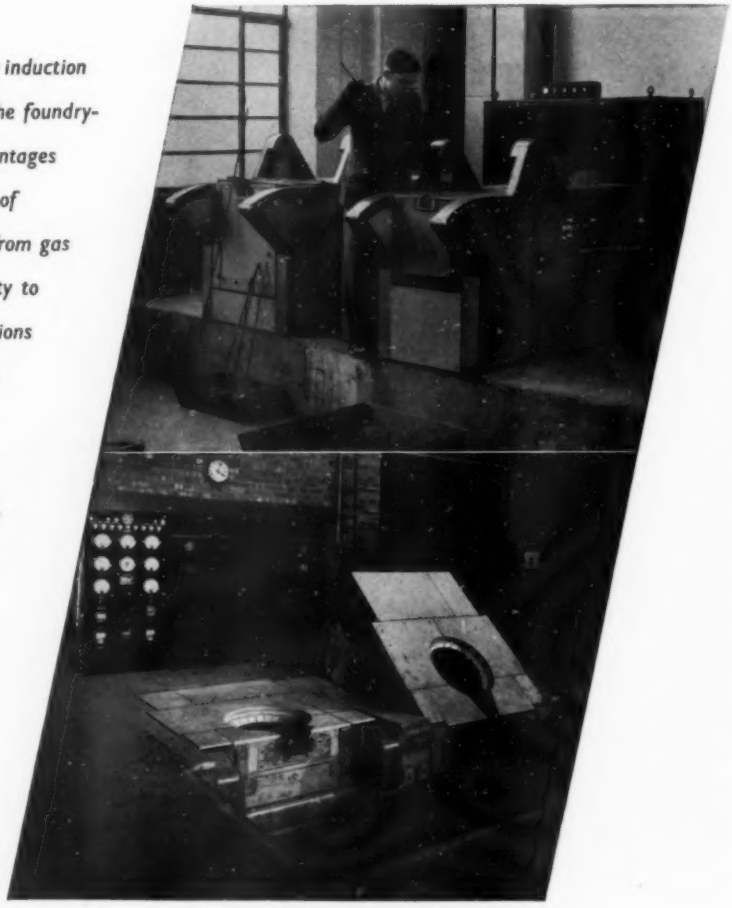

Two BIRLEC-Northrup induction melting installations are illustrated : upper picture — 100 lb. and 200 lb. furnaces : lower picture — two 1 ton furnaces.

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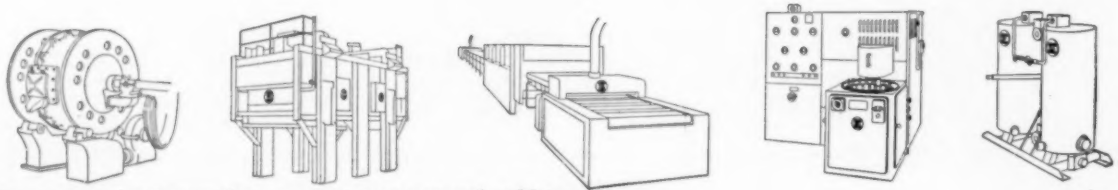

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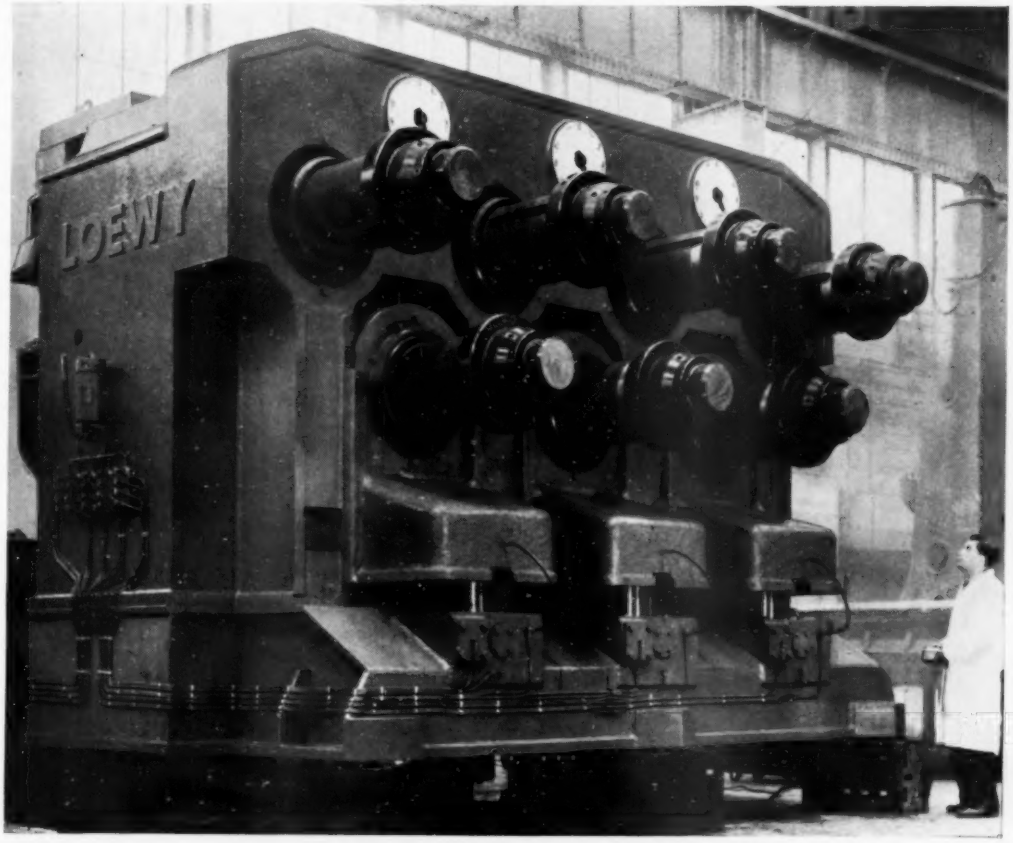

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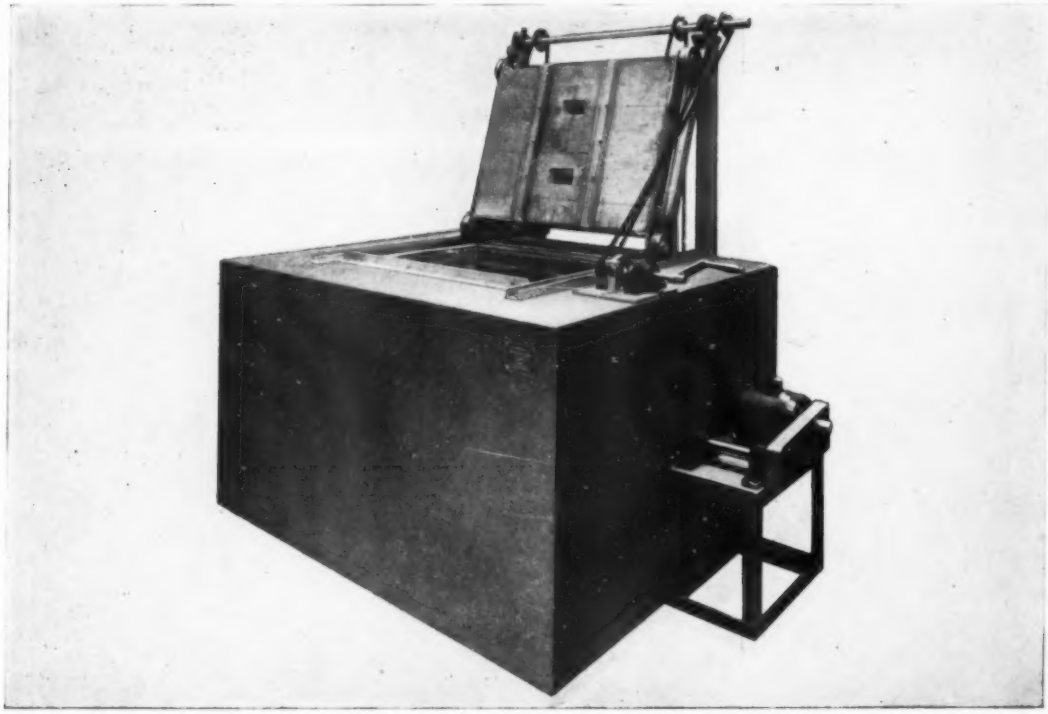

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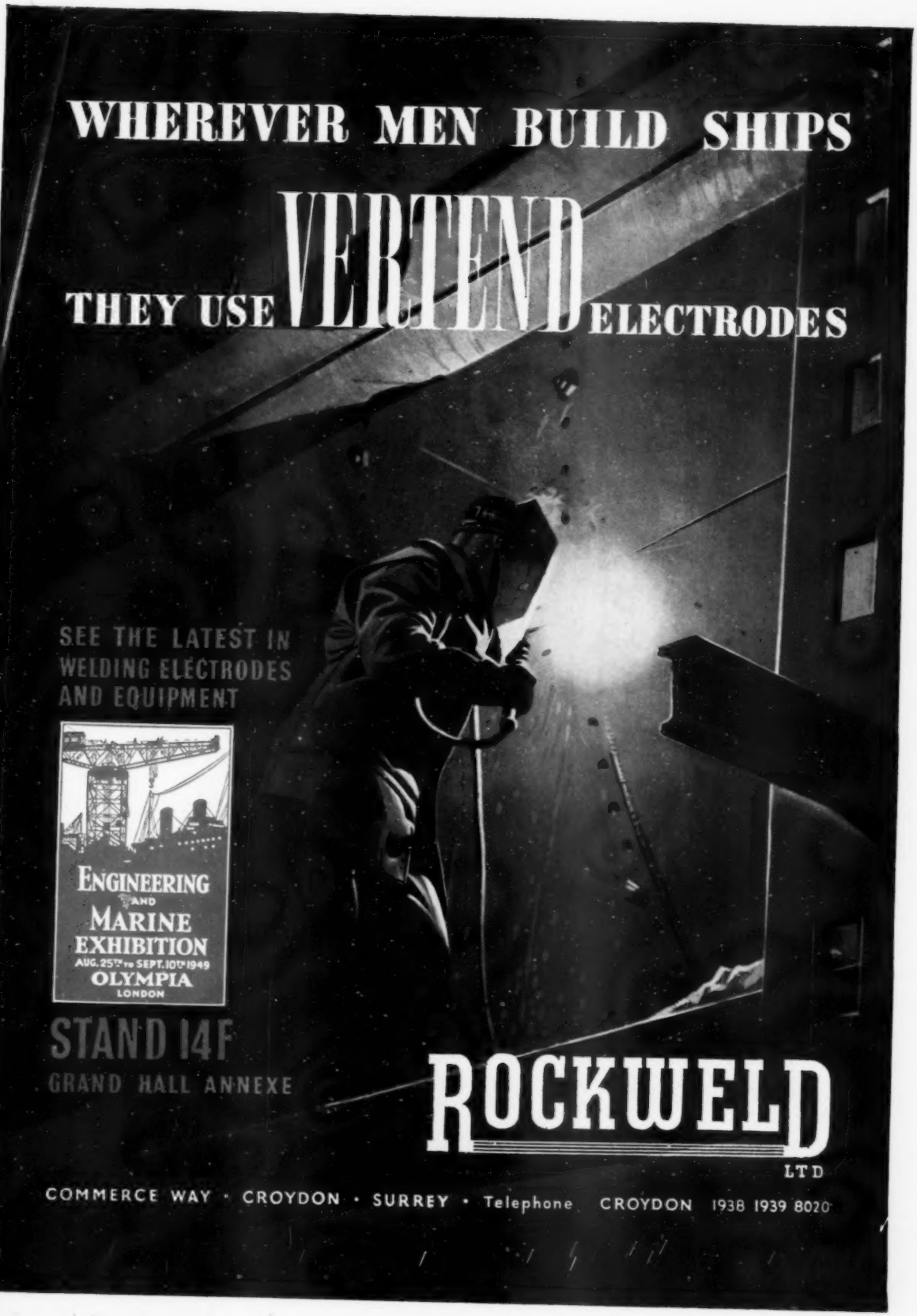

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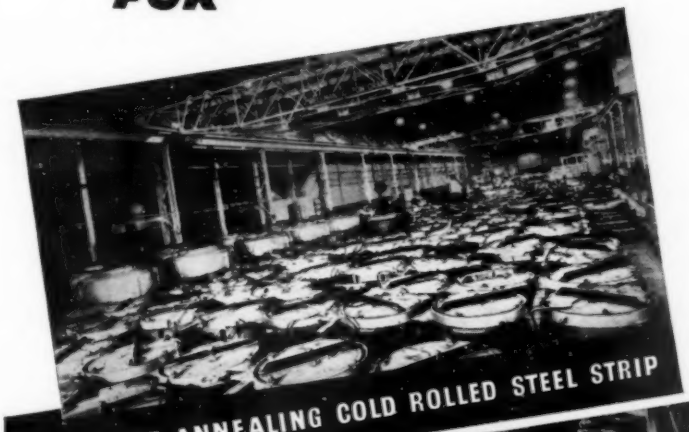

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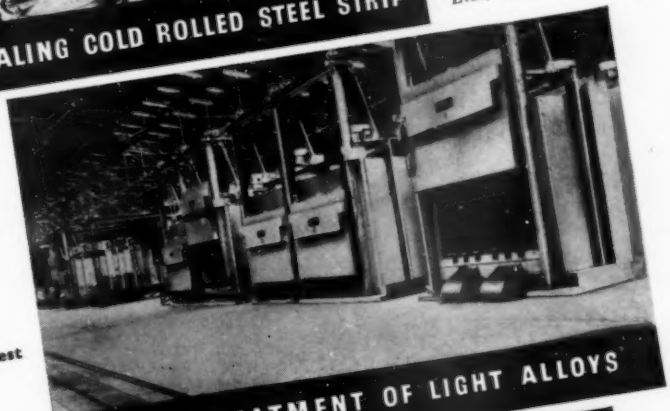
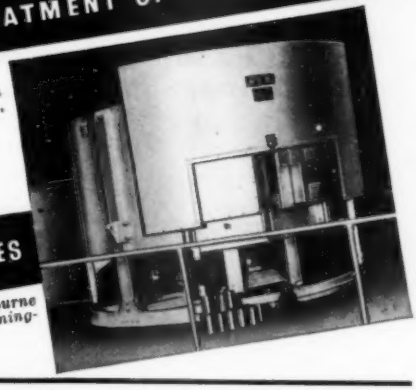


HEAT TREATMENT OF LIGHT ALLOYS

Photo.: The British Aluminium Co., Ltd., Falkirk.



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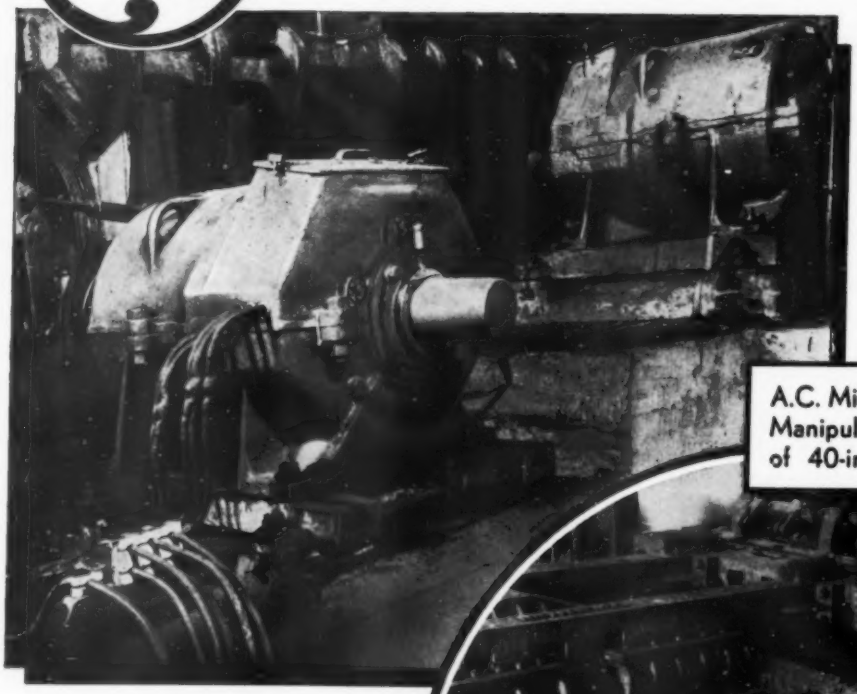
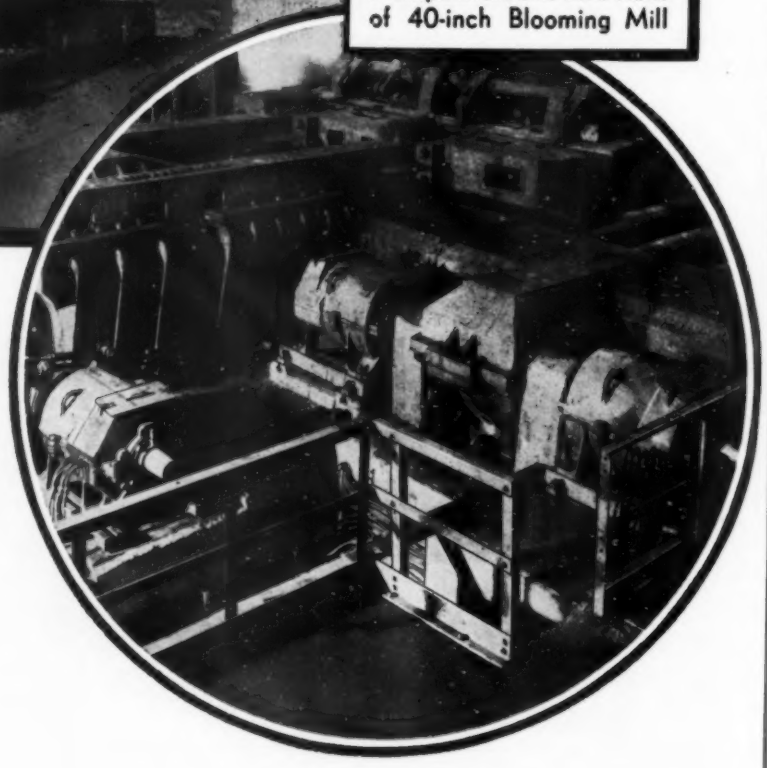


A.C. Mill Motors operating Manipulators and Live Rolls of 40-inch Blooming Mill



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Hanging on to tufts of grass
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Asked why he's not become
" Alfred, the late ",
He puts his survival down
To being light in weight !

TJP aluminium alloys are always climbing in the esteem of their users. They are perfect examples of the survival, not merely of the lightest, but of the FITTEST in EVERY respect for the work they have to do. Of course all standard specifications are available. Then there are some particular pets of our own which a number of customers consider worthy of frequent repeat orders. But these are not all. Our research people delight in devising the new and novel, so if you want a special aluminium alloy for an unusual purpose let PRIESTMANS co-operate in its production. Remember, you can always rely on a TJP aluminium alloy being consistent to the original specification.

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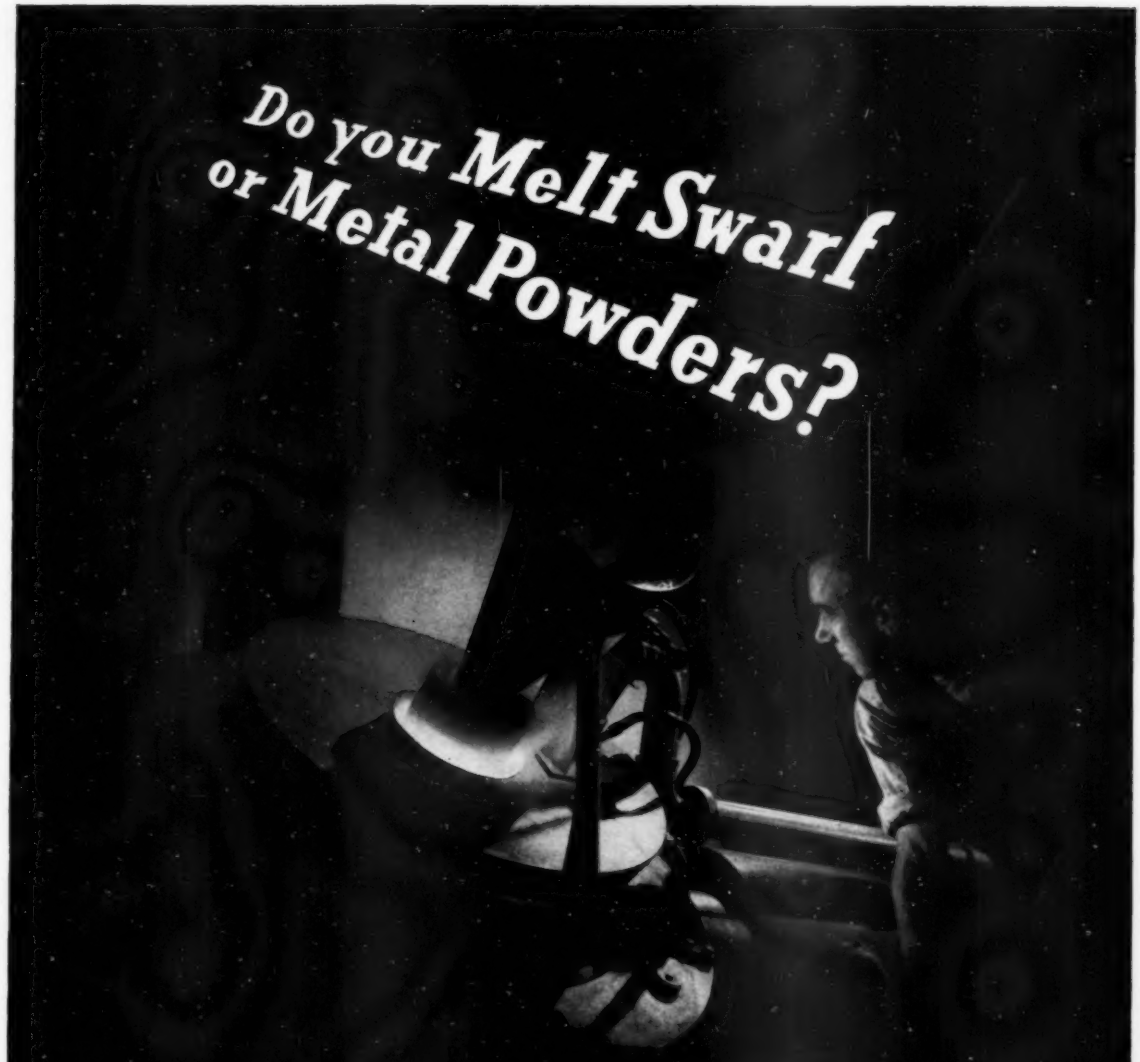

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F1.

Useful Molybdenum Steels

Data Sheet 2

SPECIFICATION Nos. TENSILE STRENGTHS 40-100 tons/sq.in.
MINIMUM IZOD VALUES AND RULING SECTIONS-
FOR HARDENING & TEMPERING

Tensile Minimum Tons/Sq. In.	RULING SECTIONS IN INCHES							
	Up to 1⅛"		Up to 2½"		Up to 4"		Up to 6"	
	B.S.En No.	Izod	En. No.	Izod	En. No.	Izod	En. No.	Izod
40 tons							13	40
45							16	40
							17	40
							19	40
							29	40
							100	40
							110	40
							160	40
50					16	40	17	40
					19	40	24	40
					100	40	29	40
					160	40	110	40
55			16	40	17	40	24	40
			19	40	110	40	25	40
			100	40			27	40
			160	40			29	40
60	16	35	17	35	24	35	25	35
	100	35	19	35			26	35
	160	35	110	35			27	35
							28	35
							29	35
65	17	35	24	35	29	35	25	35
	19	35					26	35
	100	35					27	35
	110	35					28	35
70	19	30			25	30	26	30
	24	30			27	30		
	110	30			28	30		
					29	30		
75/85 and 80/90	24	25	25	25			26	25
			28	25				
100	24	8	25	10	26	10	30B†	15
			29	10		* Air Hardened		
			30B*	15		† Oil Hardened		

FOR OUTSTANDING STRENGTH TOUGHNESS ENDURANCE

Specify MOLYBDENUM STEELS

The presence of Molybdenum gives steel the ability to harden to great depth. Because of this effect, alloy steels containing Molybdenum can be heat-treated to develop the high combinations of strength, toughness and endurance required by the modern designer.

Remember also that of all the elements which markedly increase the hardenability of steel, Molybdenum is the only one which is not lost by oxidation from the molten bath. Consequently the hardenability imparted by Molybdenum can be closely controlled.

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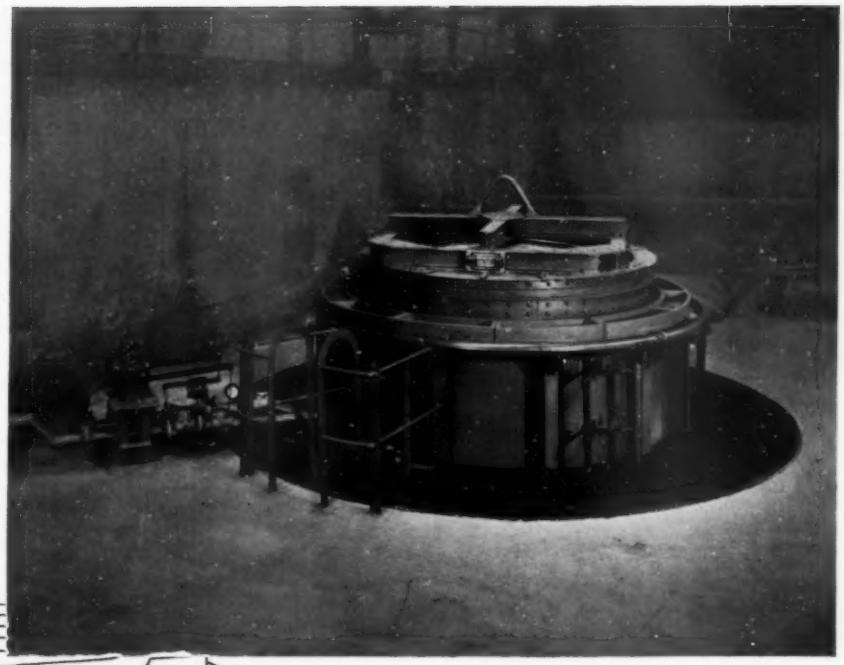

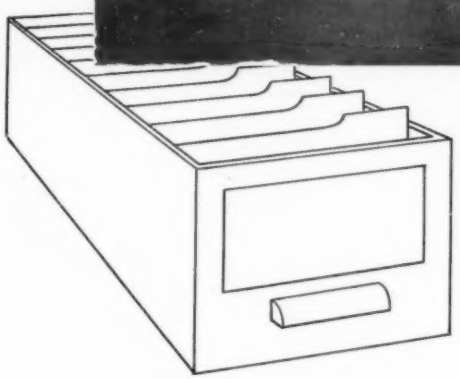

The photograph shows a Vertical Tempering Furnace fired by Coke Oven Gas and designed for the treatment of wheels after water spraying. It is 6 ft. internal diameter, and gives an output of six wheels per hour, each 48 in. diameter and weighing 1,350 lb. heated to 650° C.

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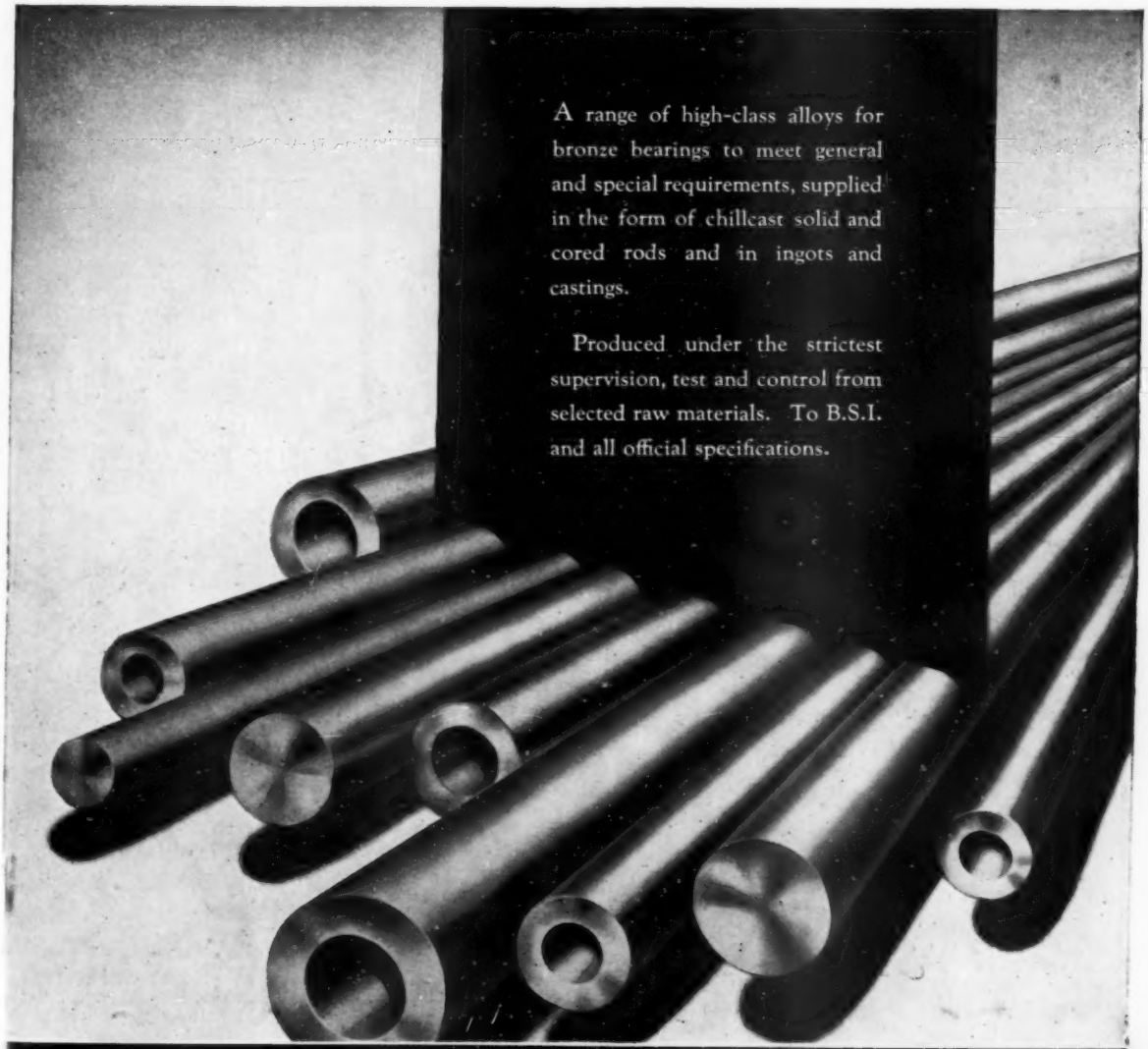

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PRINCIPAL CONTENTS IN THIS ISSUE:

	Page
Britain Shows Her Skill	183
The Search for Uranium Ores	184
Dorman Long's Lackenby Plant ..	184
Dr. Hume-Rothery Honoured	184
High Duty Applications of Acid-Resisting Silicon Iron. By R. V. Riley, Ph.D., B.Sc., A.I.M. ..	185–188
Although silicon-irons have been well known in the chemical industry for many years, their use at relatively high temperatures and pressures is a recent development.	
The Estimation of Oxygen in Metals by Hydrogen Reduction. By W. A. Baker, B.Sc., F.I.M. ..	188–189
The modifications in equipment and technique, resulting from several years' experience with the B.N.F.M.R.A. apparatus for the determination of oxygen in metals, are described.	
Steel-Making for Castings. By E. C. Pigott	190–193
The electric induction, rotary, and acid and basic open-hearth processes are considered in this concluding instalment.	
Phosphate Processes for Iron and Steel with Special Reference to Rust-proofing. By E. E. Halls	193–199
Some test results are presented in support of the claims made for the effectiveness of phosphate treatment of iron and steel before painting. More recent applications in the fields of wear resistance and lubrication in drawing and pressing operations are also considered.	
The Dislocation Theory of Slip. Recent Developments in Britain. By F. R. N. Nabarro	199–205
As time goes on, our knowledge of the fundamental nature of metals increases as a result of the labours of the metal physicist. An outline is given of the three main British developments of the dislocation theory of slip.	
Fourth Empire Mining and Metallurgical Congress	206–208, 228
An account is given of some of the papers presented at the technical sessions.	
The Engineering and Marine Exhibition	209–227
An account is given of some of the displays likely to be of interest to readers at the world's largest exhibition of engineering products to be held at Olympia from August 25th to September 10th, 1949	
New Aluminium Bookstall	227
Amperometric Titration. By J. T. Stock	229–230
The Sub-micro Balance and Its Applications. Part II—Technique and Applications. By G. Ingram	231–232
Miscellaneous Micro-chemical Devices —XX. The Control of Swings in Semi-micro Weighing. By J. T. Stock and M. A. Fill	232
Metallurgical Digest	233–236

The articles in this Journal are indexed in *The Industrial Arts Index*

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METALLURGIA

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AUGUST 1949 Vol. XL No. 238

Britain Shows Her Skill

Engineering and the National Drive

THE nation which built the *Queen Mary* and the *Queen Elizabeth*, not forgetting that masterpiece of a former generation, the old *Mauretania*, should have much to show the world at an event such as the Engineering and Marine Exhibition to be held at Olympia from August 25th to September 10th, and from a study of the exhibits it seems unlikely that the visitor will be disappointed.

At a review of the Fleet at Spithead early in the present century the steam turbine for ship propulsion made a dramatic appearance in the tiny *Turbinia* which dashed up and down the line of ships at a speed exceeding 30 knots. Since that time many rival systems—straight Diesel, Diesel-electric and turbo-electric—have made their debut and each has its advocates. For a certain type of vessel one may be more suitable than another but there is a good deal of overlapping and all are in use. Into this field the gas turbine, whose development received such an impetus during the war in connection with the jet propulsion of aircraft, makes its entrance and one of the exhibits will be the first gas turbine unit ever to propel a ship at sea. A discussion of the relative merits of the gas turbine and other forms of power unit, for ship propulsion, is not within our province but there can be no doubt that, in this field as in that of jet propulsion, much will depend on the ability of the metallurgist, using the term in its widest sense, to develop, manufacture and fabricate materials which will be capable of withstanding the conditions prevailing in the engine.

The efficiency of the gas turbine increases with the operating temperature and it is obvious that its progress will depend on the extent to which that temperature can be raised which will, in turn, be dependent on the development of reasonably priced alloys capable of operating at the higher temperatures. The experience gained with aircraft engines will undoubtedly prove valuable but there is one essential difference. Whereas the jet engines were designed for a life of some 300 hours, the designer of gas turbines for land and marine use must think in terms of tens or even hundreds of thousands of hours. Furthermore, the fuel oil used in aero-engines is of a fairly high grade but for economic reasons the commercial gas turbine may have to be run on lower grade oil or even on pulverised coal, both of which will make further demands on the constructional materials. It is encouraging to know that both on the design and material sides the problems are being energetically pursued by such organisations as Pametrada and the National Gas Turbine Establishment along with individual metallurgical and engineering concerns.

One could hardly expect every exhibit to be unique, or even novel, but the improvements incorporated in existing types of equipment are the outcome of those same processes of creative design, backed up by experimental investigation, and it is as a means of demonstrating these improvements to both the home and foreign buyer that such exhibitions justify their existence.

The number of exhibitors has topped the 500 mark, which is a record, and it is hoped that the volume of overseas trade which results will likewise be of record proportions. The engineering trade has already made a great contribution towards the country's drive for recovery—the 1947 export figures of £180 million were more than three times those for 1939—and with the industry concentrating on the replacement of old machines by the most up to date plant available there should be a speed-up in production and a lowering of prices to a really competitive level in the world's markets. Foreign buyers will much appreciate the presence at the Exhibition this year, and for the first time, of a stand by the Commercial Relations and Export Department of the Board of Trade which will, besides dealing with all export questions, be able to facilitate the export procedure for contracts placed during the period of the Exhibition.

At this year's Exhibition, the organisers are seeking to make use of the occasion for something more than a commercial enterprise and to link this demonstration of engineering skill with the national drive for greater production efficiency, such as we as a nation realise will be so necessary in an increasingly competitive world. In furthering this aim they have deliberately gone from the machine to the man who makes the machine and have issued invitations to every engineering works of consequence in the country to send organised bodies of operatives to see the results of their labours without any admission fee. They hope that thereby British engineering employees will be given a wider vision of the great contribution their daily task in the workshop makes to the welfare of their country. They also hope to stimulate efficiency and a competitive spirit by showing the operatives similar products to those with which they are concerned produced by competing firms. We feel that this far-sighted and disinterested effort to assist the nation's economic recovery is deserving of all success, for, if figures of exports and production recited over the radio and printed in the papers do little to touch the imagination of millions employed on humdrum tasks and often in necessarily uncongenial surroundings, the spectacle of the shining machines which are the sum of those efforts being actually sold to buyers who have come from the five Continents to see them cannot be anything but a stimulus to the still greater effort that we know to be essential to our national well being.

The Search for Uranium Ores

Samples Assayed and Expert Advice Given

THE present-day prospector looks for uranium instead of gold. The man who discovers a rich deposit of uranium has an opportunity of entering on the ground floor of a new industry which, a decade or two hence, is likely to govern a great many of mankind's activities.

To promote exploration throughout the Colonial territories for ores of uranium, the Geological Survey of Great Britain D.S.I.R. (Atomic Energy Division), has produced a short technical pamphlet entitled "A Prospector's Handbook to Radioactive Mineral Deposits." The pamphlet has been published for the D.S.I.R. by H.M.S.O., price 6d. (20 cents U.S.A.), by post 7d. It provides the fundamental scientific information necessary to guide prospectors, geologists and mining engineers in their widespread search for those mineral deposits which form the basis of all developments in the field of atomic energy.

The British Government has made great investments in atomic energy installations, and the Ministry of Supply has recently guaranteed that over the next ten years it will purchase all the high-grade uranium ore that can be produced in the Colonial Empire, at a minimum price of £1,540 per long ton (13s. 9d. per pound) of contained uranium oxide. In appropriate circumstances, the Ministry will give grants towards the development of producing mines and for the erection of extraction plants. Such a guarantee is a challenge to the prospecting teams which, throughout the African continent and elsewhere in the British Commonwealth, help to meet the ever-increasing demands for mineral resources of all kinds.

Although the demand for uranium is acute and increasing, there is no reason to fear that the mining world will not be able to meet the requirements of this new atomic industry. Towards the end of last century the world production of uranium oxide was not more than three tons per year; but by 1939 world output had risen to 600 tons. To-day, although production statistics are not available, it is safe to say that the world is producing some thousands of tons of uranium annually. Millions of tons are known to exist in very low-grade deposits which may, however, require many years of research by the chemist and metallurgical engineer before economic methods of extraction can be discovered. It is to these deposits that the world may ultimately look for its principal source of power, just as to-day the supply of gold comes from low-grade ores that are no richer than the waste from many early mining operations. But for the moment, our uranium must necessarily come from the higher grade deposits; and just as in the California gold rush of a century ago it was the rich pay dirt and not the low-grade ore that formed the prize of the prospector, so to-day his eyes are turned towards pitchblende, the principal mineral source of uranium.

To help prospectors, the Atomic Energy Division of the Geological Survey is prepared to assay and report on samples of uranium ore encountered during explorations in those countries from which the British Government might draw supplies. The lucky man who strikes it rich will have at his elbow all the expert advice and scientific equipment of this atomic age, and he can rest assured that a long-term market for his output is almost certainly guaranteed.

Dorman Long's Lackenby Plan

DORMAN LONG announce that the second stage of their major development plan is to be put in hand immediately, involving a further capital expenditure of over £8,000,000. This second stage includes the building of the projected open hearth steel plant at Lackenby with a capacity of 10,000 tons of ingots per week, extension of the new ore grading plant at the Cleveland works and the installation of new blast furnace ancillary equipment. It is anticipated that all this work can be completed by September, 1952.

The first stage of the Company's comprehensive development programme was the installation of central ore unloading equipment and ore preparation plant at the Cleveland works together with a private railway line over 3 miles in length across the Lackenby site and linking the Cleveland and Redcar works. These two projects, costing nearly 2¼ million pounds are now in successful operation.

The design of the ore preparation plant made provision for extending its capacity. It has now been decided to undertake this extension and so make supplies of prepared ores available to more blast furnaces.

The major development plan includes new blast furnaces at the Cleveland works and the installation of ancillary blast furnace equipment at these works will fit in to the blast furnace building programme, and meanwhile, will further assist in reducing the cost of iron manufacture at the existing furnaces.

Simultaneously with the carrying out of the first stage of the development plan extensive preparation of the site of the Lackenby Works, covering 650 acres, has been virtually completed. It is now possible, therefore, to proceed without delay with the actual work of constructing the new open hearth steel plant.

The construction work now to begin is part of the national development plan for the steel industry approved by the Government and is in line with the movement towards greater concentration of North-East Coast steel production. This national plan includes installation in the Lackenby area of extensive steel rolling mill equipment as circumstances permit.

The first stage of the development plan having been completed by the Company, continuity of development is assured by the decision now announced to proceed with further major plant installations on a considerable scale. It is noteworthy that approximately 60% of the work will be undertaken by the engineering departments of the Company and by its subsidiaries.

Dr. Hume-Rothery Honoured by Franklin Institute

DR. WILLIAM HUME-ROTHERY of Oxford has been awarded the Francis J. Clamer Medal by the Franklin Institute of the State of Pennsylvania, "in recognition of his brilliant work in scientifically determining and interpreting the structure and behaviour of metallic equilibrium systems."

The Francis J. Clamer Medal, a silver medal and certificate, was established in 1943, to be awarded not less than once in five years for meritorious achievement in the field of metallurgy. It will be presented to Dr. Hume-Rothery on October 19 by Richard T. Nalle, President of the Franklin Institute, at traditional ceremonies in Philadelphia, at which time a number of other awards will also be made.

High Duty Applications of Acid-Resisting Silicon Iron

By R. V. Riley, Ph.D., B.Sc., A.I.M.

Research Manager, Staveley Iron and Chemical Company, Ltd.

Although silicon-irons have been well known in the chemical industry for many years, it is only in recent years that improvements in consistency, strength and reliability, have led to their use at relatively high temperatures and pressures. The author discusses the manufacture of silicon-iron heater tubes designed to carry live steam at about 100 lb./sq. in. while immersed in dilute sulphuric acid.

IRON-SILICON alloys containing upwards of 14% silicon have been well known in the chemical industry since the discovery of their excellent acid-resisting qualities by Jouve, a French metallurgist, in 1908. Despite the discovery of stainless steels, high chromium irons, nickel-silicon and nickel-molybdenum alloys and the continued developments in the application of lead, ceramics, fused silica, noble metals and plastics, silicon-iron is still favoured as a constructional material for acid plant.

Many industries demand constructional materials which can claim a high degree of resistance to corrosive media coupled with metallic properties. The unique combination of these properties in silicon-iron is certainly the main reason for its continued and ever-widening popularity in the chemical and kindred trades.

Hitherto in most of the industrial applications, castings of acid-resisting silicon-iron have been employed only in a relatively unstressed condition, working either at atmospheric, or at the most, water gauge pressure of not more than a few inches. It may not indeed be common knowledge that this alloy can be used under any other conditions. Of recent years, however, owing to the great improvements in its consistency, strength and reliability, silicon-iron is becoming increasingly used for plant working at relatively high temperatures and pressures.

Silicon-Iron v. Sulphuric Acid

From a corrosion resistance point of view, silicon-iron occupies the prime position as the metal best suited for the manufacture of equipment for sulphuric acid concentrating plant. Throughout two world wars it has stood alone as the most satisfactory commercially available material for this type of acid plant. Recent developments in chemical engineering have resulted in the production of a new type of sulphuric acid concentrator which makes very severe demands upon the alloy. Messrs. Simon Carves are responsible for the introduction to this country of this plant in which weak sulphuric acid is brought up in strength to 93% under fume free conditions by means of a Vacuum Concentrator. The contract for the silicon-iron parts of these concentrators was given exclusively to Messrs. Bradley and Foster, Ltd., Darlaston, S. Staffs., where the various castings were executed in Hypersilid 14–16% alloy.

Heater Tube Castings

A vital part of the concentrator is a heater tube, having a closed end, totally immersed in dilute sulphuric acid and carrying live steam at about 100 lbs./sq. in. Two types of heater tube have been made in silicon iron, the first were 5 ft. long × 7 in. outside diameter,

Fig. 1.—Silicon-iron heater tube.

and the second series were 6 ft. long × 7 in. outside diameter. The finished casting shown in Fig. 1, which is an example of the larger type of tube, weighed 318 lb. The minimum thickness of this heater tube at any point was $\frac{3}{4}$ in. and maximum was $\frac{15}{16}$ in. The variation in wall thickness between any four places at any selected section had not to exceed $\frac{1}{8}$ in. provided none of these measurements fell outside the former limits of thickness. The tolerance on wall thickness for the unmachined sand casting was therefore $\pm \frac{1}{16}$ in. The maximum permitted departure from the straight was $\frac{1}{4}$ in. over the 6 ft. length of tube.

The open end of the tube was provided with a flange $11\frac{1}{2}$ in. in diameter and a projecting spigot which terminated in a cone end joint. The flange and jointing section were machined on all faces. Silicon-iron is a very hard alloy and the machining of this end was a grinding operation. Each casting was identified by a serial number cast on the nose end and a complete record of inspection data was filed.

Foundry Technique

It is not permissible to make silicon-iron castings with chaplets. The whole of the core for this blind-ended tube had to be located and secured in position from the open end. To work to the desired fine tolerances necessitated special mechanical arrangements to hold the core rigidly in position during casting. The unique moulding box and core assembly shown in Fig. 2 was used. This consisted of a two-part box of hexagonal cross-section having open ends which were accurately squared and machined to provide locating faces for a loose nose end moulding box at one end and the special core barrel collet at the other.

The core was made by loam moulding on a machined core-barrel working in machined bearings. The loam

board was a fixture. A loose plug of the same diameter as the core barrel was provided which served as one of the journals during core making and for handling purposes during stoving. This plug was screwed from the end of the core barrel just prior to setting up in the mould, the hole being made up with loam. Wood wool rope wound on to the core barrel served as a foundation for the loam which was of special consistency calculated to collapse readily after the pouring of the iron.

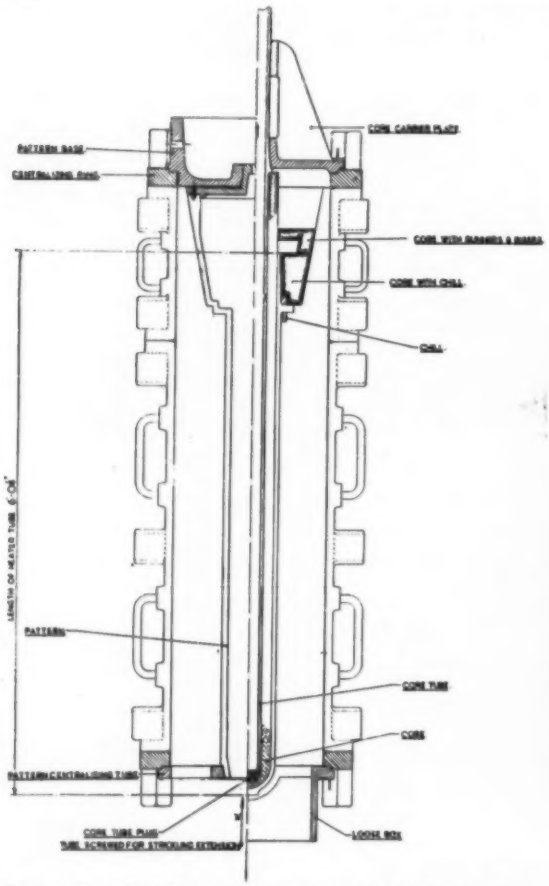


Fig. 2.—Moulding box and core assembly for heater tube.

The moulding box was placed vertically in a pit, suspended from brackets on the side, leaving 3 ft. clearance at the bottom.

Fig. 3 shows the moulding box assembled in the pit. The mould was hand rammed around a full length steel pattern located in the collet at the top and a removable ring at the bottom. A natural sand was used, blended to give a dry sand mould having adequate strength when stoved, but being readily collapsible after pouring. The mould was rammed with the detachable nose box in position. This small box was removed from the mould from underneath to enable the core to be set accurately. The nose end mould was replaced for casting. The flange and cone contour of the open end of the tube were obtained by means of an oil sand core which also served as a pouring basin filling the mould via pencil sprues.

The mould was cast with silicon-iron at a temperature of 1,320° C. (optical) and exactly seventeen minutes later the core barrel was drawn. The mould was removed from the pit, put on its side on the foundry floor and the box opened so as to ease the sand around the flange. The casting was then left to cool slowly in the box. Taken from the moulding box when cold the casting was fettled by grinding and was then ready for inspection and testing.

Inspection and Testing

Each casting was subjected to an extremely thorough and extensive programme of inspection and testing carried out by the manufacturers and a final inspection

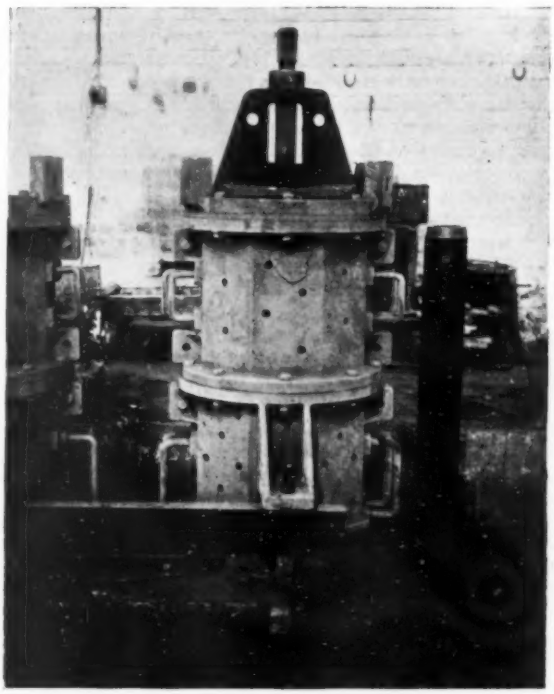


Fig. 3.—Mould assembled for casting.

in the presence of representatives from Messrs. Simon Carves, Ltd., a boiler insurance company and the customer.

The first inspection of the casting was made by the Work's Inspector before machining. Dimensional checks were carried out, using a specially designed wall thickness measuring machine. The quality of the inside of the tube was then approved by a detailed examination with the Foster Intrascope, an optical device which enables the eye to see every part of the internal surface of the tube, including the closed end. A casting passing this first inspection was then hydraulically tested at 100 lbs./sq. in. and approved for machining.

When the grinding of the flange and open end of the tube was finished, the casting was transferred to an acid pickling tank (Fig. 4). The pickling process was carried out at 80° C. in 30% sulphuric acid until all effervescence ceased. Then followed a final check upon dimensions in the presence of outside inspectors and a

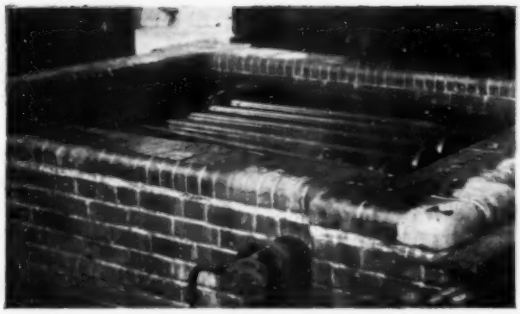


Fig. 4.—Acid pickling tank.

pressure test with Kerosine under 400 lbs./sq. in for 30 minutes. No pressure drop under this test was allowed.

Despite the very stringent inspection and testing programme, an extremely formidable specification for castings in any metal, large numbers of heater tube castings have been produced. Some 152 short tubes and 168 long tubes have been supplied to the cutomers. The first batch it is understood, has given complete satisfaction to the user, and was completed in July, 1944. The last order for the longer tubes was finished early this year some six months after the acceptance of the contract.

Metallurgical Considerations

Silicon-iron for high duty castings requires very careful preparation. Electric furnace melting of the iron is practised at Messrs. Bradley and Foster, Ltd. First an ingot is made from carefully selected raw materials, refined pig iron, steel scrap and high grade ferro-silicon. It is very important to select only raw materials known to be low in hydrogen. The ingot is remelted together with foundry scrap in a 30-cwt. three-phase direct arc furnace.

The metal for castings must be checked for gassiness before using. This practical test is made by the pouring of a sampling spoon of molten iron into a prepared sand mould and during solidification its surface is carefully watched for signs of bleeding back. It is important to keep the hydrogen content of silicon-iron below 2 mls./100 gms. in order to avoid porosity. It is equally important to prevent the approved iron making contact subsequently with any wet patches on the lip of the ladle

Fig. 5.—A selection of castings in acid-resisting silicon-iron.

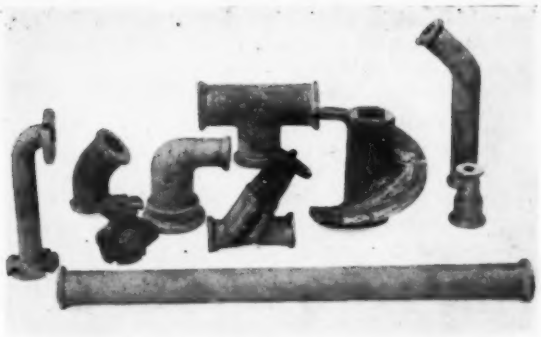


Fig. 6.—Complex castings in acid resisting silicon-iron.

or damp runner bushes, and furnace repairs must be carefully dried out before melting silicon-iron.

It is also important to keep the carbon content of the iron within the optimum range which with the Hypersilid alloy, is 0·60%–0·65%. This ensures the absence of kish inclusions on the one hand and undue shrinkage on the other. For adequate resistance to corrosion the silicon content is kept about 14·5%. The manganese and phosphorus are 0·6% and 0·2% respectively.

TABLE I.—PHYSICAL AND MECHANICAL CONSTANTS OF CHEMICAL WARE.

	Hypersilid 14/16	Cast Iron	Stoneware
Weight in Pounds per Cu. Ft.	428	445	136
Density in Grams/Cub. Cm.	7·0	7·3	2·2
Melting Point, °C.	1,250	1,200	1,450
Specific Heat	0·130	0·115	0·20
Co-efficient of Expansion (× 10^{-6})	12·0	12·1	4·5
Thermal Conductivity (Cals. per cm. per sec.)	0·078	0·110	0·0023
Electrical Resistivity (Micro-ohms. per cub. cm.)	50	45	—
Hardness (Brinell)	450	180	—
Tensile Strength (Tons/Sq. in.)	10·0	15·0	1·0
Transverse Strength (Tons/Sq. in.)	18·0	30·0	—
Modulus of Elasticity (E=lbs./sq. in. × 10^6)	17·0	19·0	—

The physical and mechanical properties of Hypersilid alloy are now firmly established and are shown in Table I. It is convenient to compare silicon iron with cast iron and with stone-ware as all these three materials are commonly used in the construction of chemical plant. When the outstanding acid resisting qualities of silicon-iron are considered along with the mechanical properties as revealed in the table, the reason for the success of this alloy in the chemical industry is self evident.

British Standard Silicon-Iron Castings

The heater tube casting described was one which required more than ordinary care and ingenuity in manufacture and was subjected to very severe inspection and testing. Silicon-iron manufacture in this country is, however, on a very sound footing and many castings are made in the course of an ordinary day's work which match this example, in complexity or degree of reliability expected in use.

All silicon-iron pipe work for example, is manufactured to British Standard No. 1333, 1946, which calls for a high degree of dimensional accuracy and quality of casting, and a hydraulic test to 50 lbs./sq. in. before leaving the works. Silicon-iron valves and cocks are

also made which are subjected to pressure tests of 50 lbs./sq. in. with Kerosine. Some intricate castings are shown in Figs. 5 and 6.

Conclusion

Chemical plant in which silicon-iron can be used advantageously need no longer be limited to low working pressures. The silicon-iron heater tube using steam at 100 lbs./sq. in. is an established fact. Other plant is known in which satisfactory performance has been obtained under mechanically stressed conditions and there is little doubt that a more widespread use of this valuable corrosion resistant alloy may be contemplated.

Acknowledgments

Acknowledgments are made to Messrs. Simon Carves, Ltd., Stockport, and to Messrs. Bradley and Foster, Ltd., Darlaston, for permission to publish this article.

The Estimation of Oxygen in Metals by Hydrogen Reduction*

By W. A. Baker, B.Sc., F.I.M.†

(*Communication from the British Non-Ferrous Metals Research Association.*)

In the light of several years' experience in using the British Non-Ferrous Metals Research Association's apparatus for the determination of oxygen in certain metals, modifications have been made in several aspects in order to increase the accuracy and speed of analysis. In this article, the author describes the modified equipment and its use.

FOR some years, the British Non-Ferrous Metals Research Association has used a method for the estimation of oxygen in certain non-ferrous metals in which the sample is heated in a closed system in contact with a small excess of pure hydrogen, the water vapour formed being condensed during the reduction and subsequently vaporised, in an otherwise exhausted system, to measure its amount. The original apparatus was described[1] in a paper which included results of tests on lead, lead-tin alloys and copper showing that oxygen contents of the order 0·0002% upwards were readily determined. The apparatus has been modified in several respects to increase the accuracy and speed of analysis, as described in the present communication.

Description of Apparatus

The apparatus is shown diagrammatically in Fig. 1 and comprises a clear silica combustion tube connected by a greased flange joint to a soda-glass system, which in turn is connected to a Hyvac oil pump capable of exhausting the system to approximately 0·001mm. mercury. A pot type platinum wound furnace is provided to heat the inclined part of the silica combustion tube which is approximately 25mm. bore, 15 in. in overall length and has a wall thickness of 1·5mm. The glass tubing in the remainder of the system is approximately 5mm. bore and the volumes of the spare bulb and the hydrogen reservoir are respectively 72 c.c. and 140 c.c. The total volume enclosed by the taps A, C and B, i.e., the volume of the water trap plus the mercury manometer and associated tubing is approximately 44 c.c.

The taps are of the hollow barrel type with a hole through the barrel 3–4mm. in dia. This feature is important because if the solid barrel type is used, tap grease films tend to block the orifices and cause difficulty in exhausting small quantities of gas from the system. The tap A is preferably of larger bore, e.g., 8mm., so that the path of water vapour diffusing from the combustion tube to the water trap in the analytical system is not unduly restricted.

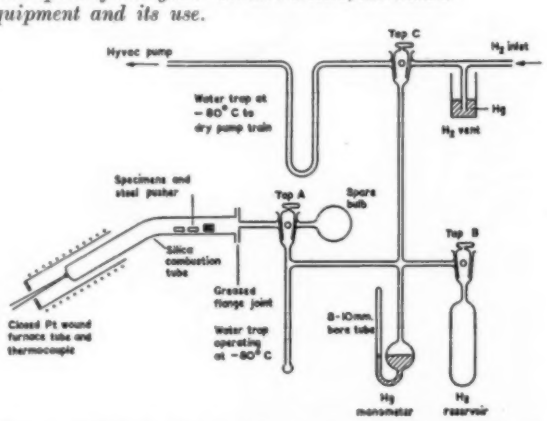


Fig. 1. Diagram of apparatus for the estimation of oxygen in metals by hydrogen reduction.

Further details of the apparatus will emerge from the following description of analytical procedure.

Analytical Procedure

One or more specimens, cleaned by filing with a clean file or better by scraping with a sharp knife,[2] are inserted in the upper horizontal part of the combustion tube followed by a small steel pusher, taking great care to avoid contaminating the surfaces of the specimens with grease from the joint at the end of the tube.

A thermos flask containing a mixture of solid carbon dioxide and acetone (which remains at −80° C.) is placed on the water trap in the pump train and the glass system and silica combustion tube are exhausted by appropriate manipulation of taps C, B and A. Hydrogen from a cylinder of the commercial purity gas is passed through a water trap at −80° C. and then into the tube attached to tap C, the gas being allowed to bubble out through the mercury vent shown. Tap C is then opened and hydrogen is slowly admitted to the

* *B.N.F.M.R.A.* Report R.R.A. 492 P (Revised).
† Senior Metallurgist, B.N.F.M.R.A.
1 *Jnl. Inst. Metals*, 1939, **65**, 345.

2 Cleaning with acids, particularly oxidising acids, is liable to leave films on the surface of the specimen which give rise to high results.

apparatus, utilising the mercury vent to avoid entraining air. The hydrogen is allowed to fill the whole apparatus including the hydrogen reservoir. Hydrogen in the reservoir is then trapped by closing tap B and the rest of the apparatus is again exhausted by the pump.

Tap C is closed and hydrogen is admitted to the glass system and the combustion tube via tap B until the pressure indicated by the manometer is approximately 30–50mm. Hg. The combustion tube is then heated to the temperature at which specimens will be reduced,[3] and a solid carbon dioxide/acetone mixture is applied to the water trap of the analytical system. After 30 min. heating the bulk of the hydrogen is trapped in the combustion tube by closing tap A and that remaining in the glass system is exhausted via tap C a few minutes after closing tap A ; this delay is necessary to allow time for any water vapour in the analytical system to diffuse to the freezing trap. Tap C is then closed, the condensing mixture is removed from the analytical system, and the water vapour trapped in it is vaporised by immersing the water trap tube in tepid water. The vapour pressure recorded on the mercury manometer[4] is measured with a cathetometer, or with a low power microscope with a graticule in the eyepiece of which the 100 divisions are equivalent to about 5mm. Hg pressure, and the water vapour is recondensed by replacing the cooling mixture. Tap A is opened again and combustion is continued for a further 30 min. when the previous procedure is repeated, trapping the bulk of the hydrogen in the combustion tube, rejecting the remainder, and observing the increase, if any, in the amount of the water vapour evolved from the trap. Normally, the first combustion will yield only a trace of water vapour and the second or third will establish a suitably low blanking rate, in which case the water vapour in the analytical system is vaporised and pumped out. One of the samples is then pushed into the hot zone of the combustion tube, using the steel pusher and a magnet placed outside the combustion tube, and the procedure described for the purification of the hydrogen is repeated until the additional amounts of water vapour trapped in the condenser with repetition of the reduction cycle are the same as in the initial low blanking rate.

The water vapour is then exhausted from the analytical system and if necessary, a further supply of hydrogen is admitted and purified, before proceeding with the treatment of further samples.

For the apparatus in use in the Association's laboratory, the volume of the system enclosed by taps A, B and C is approximately 44 c.c. and a water vapour pressure of 1mm. Hg is equivalent to 0·00004g. oxygen. The weight of sample chosen for analysis must be such that the water vapour pressure measured is in the range 5–10mm. Hg and preferably 4–7mm. Hg. With the mercury manometer described, the vapour pressure can be measured to $\pm 0{\cdot}05$mm. Hg and with the low blanking rate usually attained oxygen contents can be measured to within about $\pm 4\%$ of the oxygen content if a sample of suitable weight is taken. The specimens are liable to be superficially oxidised despite careful preparation and oxide films below interference colour thickness may give rise to oxygen contents of the order of 0·0001% oxygen, or more, depending of course on the surface area/volume ratio for the specimen. The figure of 0·0001% is usual for massive samples.

Water vapour pressures exceeding 10mm. Hg cannot be safely used, although the theoretical maximum possible vapour pressure of water at 20° C. is approximately 17mm. Hg. In the Association's usual procedure the pressure range up to 7mm. Hg is used. If in an analysis the water vapour pressure noted is near this limit, the (previously exhausted) spare bulb shown in the diagram should be connected to the analytical system and the resulting lower pressure observed. If the relative volumes of the analytical system and of the spare bulb are known, from prior calibration, this step will show whether the vapour pressure observed is in fact the pressure of an unsaturated vapour.

The apparatus may be calibrated by one of two means. Firstly by reduction of known weights of an oxide of known composition, e.g., lead oxide, and, secondly, by introducing a known volume of gas into the exhausted system, via a gas pipette containing a known volume of gas at atmospheric temperature and pressure. Both methods have been used and have been found to give concordant results.

Fused alumina crucibles should be used in the combustion tube ; the ordinary laboratory alumina ware is unsatisfactory because it is too porous and slowly evolves large amounts of water during the blanking operation.

Applicability of the Method

The method is obviously only applicable to those metals and alloys in which oxide phases can be reduced by hydrogen in the available temperature range. The Association's experience indicates that it is applicable to copper, lead and tin and to alloys of these elements but the presence of certain elements which are volatile may vitiate an analysis. For example, considerable proportions of phosphorus or zinc in copper-base alloys may interfere ; these constituents volatilise from the specimen and condense in the upper part of the combustion tube where they tend to recombine with water vapour evolved from the specimen. Consequently, if metallic mirrors or other deposits appear in the cooler parts of the combustion tube, the results should be regarded as suspect until the deposits have been shown to have no effect, as for example by adding to the previously treated melt in the combustion tube a small quantity of copper of known oxygen content, and verifying that the water vapour evolved is consistent with the oxygen content of the added material.

Errors due to volatile constituents may be minimised or avoided by using a relatively large bath of a suitable metal (e.g., tin) in the combustion tube, deoxidising the bath during the initial purification of the hydrogen, and then adding the sample to be examined to the molten bath. In this way the concentration and therefore the vapour pressure of the volatile constituent is lowered so that the amount of material distilled from the hot zone of the furnace is reduced. Again however, the effect of any distillation which persists should be examined by the method described.

Acknowledgments

The author wishes to thank the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this paper.

3 E.g., 600° C. for lead and lead-tin alloys and 1,100–1,150° C. for copper and copper-base alloys. In general it is preferable to melt the specimen and thereby speed up the extraction of oxygen.

4 The blind limb of the manometer should be 8–10mm. bore to ensure that the height of the miniscus is not unduly affected by surface tension effects due to traces of grease which may concentrate on the glass surface around the zero level in the gauge.

Steel-making for Castings*

By E. C. Pigott

Chief Metallurgist, Central Marine Engineering Works, West Hartlepool

Steel, the product of some of our best inward qualities, is also the most important material of our outward civilisation. It is not only in the melting shop that a knowledge of steel-making is necessary; a grasp of at least the more important aspects of manufacture is indispensable to a correct use of the metal and it is partly with this viewpoint in mind that the author discusses the various processes by which steel suitable for castings is produced.

THE ELECTRIC INDUCTION PROCESS

As a unit for melting high-grade alloy or carbon steels, mainly for the smaller castings, the high-frequency induction furnace, used so much for ingots of tool steel, stainless steel, etc., has largely superseded the old crucible process and continues to gain in popularity.

The process is not normally used for refining. An outstanding feature is the high degree of purity of the product, owing largely to the absence of sulphurous gases. The unit is compact and the process is clean, rapid, flexible and in no way arduous to operate. Steels of any composition can be made, within close analysis limits, as melting losses, even of ferro-alloys, are remarkably low, and the naturally induced circulation of the bath provides great uniformity. Pouring temperatures are readily adjusted to suit requirements.

The Furnace.—The outer case is of non-magnetic metal and Syndanyo board. A water-cooled cylindrical copper coil, often of about twenty turns and protected by a covering of clay, surrounds a protected heat-resisting crucible or rammed receptacle of 500–2,000 lb., or more, capacity. Carefully selected refractory material is packed between coil and receptacle. Magnesite, magnesite-alumina and ganister are used, but ganister is unsuitable where manganese steels are to be melted.

High-voltage alternating current at a frequency of 1,200 or 2,200 cycles, supplied by a generator of special design, is passed through the coil and a high current is induced in the metal charge, which melts by virtue of its own resistance.

Larger furnaces, up to 5 tons or so, have a rammed lining, made around a welded steel former which, on being heated by induction, frits the lining surface thoroughly before finally melting. A well-made lining survives fifty or more heats. In order to provide adequate penetration, the larger the furnace, the lower the frequency of the applied current. Provision is made for tilting the furnace, with the spout as the axis, by means of an electric motor.

Charges of $\frac{1}{4}$–$\frac{1}{2}$ ton can be melted and cast within the hour, fifty or more heats per week being possible.

Operation.—The charge, placed in the crucible or special lining, consists of such materials as carefully selected steel scrap, blister steel, and ferro alloys, compounded to give the required analysis. The average composition undergoes virtually no change during melting.

The heavier scrap is charged first, followed by the lighter material. The current is now started, and when the melting metal starts to sink, any residual charge for which there was no room may be added. A sufficiently vigorous vertical circulation is set up by the induced eddy currents, and no further mixing is required. A secondary advantage of this agitation is that no slag line is formed to erode the crucible or lining.

When the charge has completely melted, the bath is brought to the correct pouring temperature and deoxidisers are added. After switching off the current, the heat is poured by tilting the furnace. Although the larger castings are cast from ladles, it is usual to fill the smaller moulds from preheated shanks carried by two or three men.

ROTARY PROCESS

The rotary furnace, designed primarily for melting special cast irons, attains very high temperatures and is often used as an intermittent steel-making unit. Test results comparable with those from other processes are obtained.

The furnace body consists of a horizontal refractory-lined shell mounted on electrically-operated rollers. A common capacity is 2 tons, but larger sizes are also in use. The fuel may be oil, creosote pitch, pulverised coal or gas, the incoming air being preheated in a recuperator heated by the combustion products.

Great care is necessary in drying the rammed monolithic lining, a procedure lasting two to three weeks. Before use the dried lining is glazed at a high temperature with slag, and it is advisable to melt several heats of cast iron before proceeding to make steel.

The end at which the fuel enters serves as a combustion chamber; charging is carried out at the exhaust end. An average carbon content in the charge of about 0·7% is suitable, a typical charge being 20 cwt. mild-steel scrap, 13 cwt. carbon-steel scrap and 7 cwt. hematite pig iron. By means of iron-ore additions the carbon is worked down to 0·2%. Bath samples are taken and the analysis controlled within close limits, final additions being usually adjusted to raise the carbon to 0·3–0·4%. Owing to the rapid transference of heat from the lining direct to the metal, the whole process is of only 3–4 hours' duration.

THE BASIC OPEN-HEARTH PROCESS

All but a small part of our steel is made in basic (basic-lined) open-hearth furnaces from comparatively cheap materials. This process does not provide the finest grade of steel, but with modern practice a high standard is reached. There are both fixed and tilting types of furnace ranging in capacity from 15-150 tons for the fixed type to 20 -300 tons for the tilting type. In foundry work, the smaller furnaces (15–50 tons) are used.

Essentially, the hearth, which is roughly rectangular in shape, consists of rammed burnt dolomite. The shell of the hearth consists of steel plates; these are covered with magnesite bricks and then with the dolomite. The dolomite is crushed, riddled through a plate having perforations $\frac{3}{8}$–$\frac{1}{2}$ in. dia., and mixed with dry tar. Preferably, the crushing is done shortly before use, since

* Concluded from page 158, July issue.

perished dolomite is altogether unsuitable. As each layer of dolomite is applied, it is saturated with basic slag which serves to restrain absorption of slag from the surface of the molten metal. Even so, it is only after several heats that the lining becomes fully satisfactory.

Other lining materials, used rather more for walls and roofs, are magnesite and chrome-magnesite. Hearths of magnesite should be used only with the cold-charging process. Chrome-magnesite bricks are often used in making the roof.

Regenerators.—Lying in the long shallow saucer-like hearth, the charge is exposed to the combustion of a gas-air mixture preheated in regenerators to a temperature of 900° C. or more. The air supply may be enriched with oxygen. Producer gas, or a mixture of blast furnace and coke-oven gas may be used and in some cases the furnace is oil-fired. There are two spaced-brickwork regenerators on each side of the furnace; these are alternately heated by the exhaust gases. The gas-currents are reversed every 20 or 30 minutes, depending on the temperature. Oil fuel, which provides higher temperatures and quicker melting, is slightly preheated externally, leaving only the air to be preheated in the regenerators.

The open-hearth process owes much to Sir William Siemens for his regenerative system which affords extremely high temperatures with economy, and to Martin for his development work. The chemistry of the basic process, suitable for irons made from phosphoric ore, which is plentiful in Britain, had already been worked out in connection with the basic Bessemer process by Thomas and Gilchrist.

The air ports are larger than the gas ports and are situated above them in order to promote mixing. Below the vertical flues connecting the ports with the regenerators are small chambers or "pockets" designed to catch small particles of slag and dust. At the pit side is the taphole which, in fixed furnaces, is of course sealed during the melting.

General Features.—In contrast with some steel-making processes, there is ample time for control, the working of an 80–100 ton charge occupying between 9 and 14 hours from start to finish.

Grey phosphoric pig iron plus steel scrap constitutes the charge which is introduced by mechanical chargers. The pig iron may be charged either cold or molten. Given a suitable composition, considerable advantage attaches to the use of molten iron. Not only is the initial heat of the blast furnace utilised, but the violent reaction that ensues on pouring on to the steel scrap and ore accelerates the removal of the impurities. Moreover, molten iron costs less than cold pig. From the use of cold or molten pig two distinct processes arise.

As a rule, the average phosphorus content of the charge is of the order of 0·5%. Within limits, however, attention is paid to the market value of the slag produced, highly phosphoric slags having a ready sale. The average sulphur content should be below 0·1%. Pig irons low in silicon are favoured, since the lower the silicon, the less lime is required for removal of the phosphorus.

Of great importance is the manganese content of the pig iron, high contents up to 1·5% or even 2·5% being advantageous. Manganese promotes removal of the sulphur, as manganous sulphide, which passes into the floating slag. As manganous oxide, the element also combines with some of the silica. Further it prevents over-oxidation of the molten bath.

One of the outstanding features of the process is that inferior classes of steel scrap may be used. Only very few types of scrap are unsuitable although steel scrap containing chromium is usually avoided, since chromium thickens the slag.

The material on which the entire process depends is lime, the chief component in the formation of basic slag. If unburnt limestone is used it should be charged during the earlier stages. Towards the end, when a highly basic slag is required it is preferable to use burnt (calcined) limestone, which should contain not more than 0·10–0·15% sulphur.

The most important feature of the process is the removal of much of the phosphorus as phosphorus pentoxide, which combines with the free lime to form phosphate of lime in the slag. Part of the sulphur is also removed; it enters the slag as calcium sulphide.

Most of the silicon and manganese is oxidized, entering the slag as oxides in combination with the large amount of ferrous oxide produced. The manganese content of the metal should on no account be allowed to fall below 0·2% at any time during the process, otherwise over-oxidation may occur.

The first material to be charged is the steel scrap. The flux (lime or limestone) is added, and then the pig iron. To add the pig iron first would be to invite silica-attack on the basic lining.

On the whole, rather more steel scrap than pig iron is used, but the proportion varies considerably from district to district, and according to the desired carbon and phosphorus contents of the finished steel. White irons rich in sulphur, as well as cast iron, may be included in the charge. Sometimes, iron ore is charged with the lime. Metal for castings should be hotter than that for ingots.

Cold Charge Practice

In the cold-charge method which is used where the metal is required specifically for castings, the amount of pig iron should be such as to provide enough carbon to give about 2 hours boiling, before the final carbon content is attained.

For a 20-ton charge, about 12 cwts. of lime or 24 cwts. of limestone is charged initially. In the prevention of sulphur absorption from the gas, limestone is better than lime. Proper control during the melting period greatly facilitates subsequent working. For instance, if a strongly oxidizing gas is avoided, and no ore is put in with the charge, much of the sulphur may be removed during the melting period.

As iron oxide is formed on the surface of the melting bath, nearly all the silicon is removed, followed by a proportion of the manganese and then of the carbon. To prolong the melting period unduly is to lose too much carbon and so to necessitate a further addition of pig iron.

As soon as the charge is quite melted, the bath begins to "boil." When the carbon content, as shown by fracture tests, begins to fall appreciably, the bath is fed with lime and fluorspar. Sufficient spar is used to cause the slag to lie quietly, without frothing, so that the bath can boil quite freely. Dip rods are used to check the consistency of the slag, an even coating about $\frac{1}{8}$ in. thick retained on the rod indicating a satisfactory consistency.

At this stage, a very high bath temperature is desirable. If, on analysis, the sulphur content is found to be higher

than is required in the finished steel, it is reduced by the addition of more lime and fluorspar. Fluorspar reduces the liquefying point of the slag and so makes it easier to manipulate. besides allowing it to carry more lime and so hold more sulphur.

Millscale is also added periodically to aid in the production of a suitable slag. In place of millscale, iron ore is sometimes used, but it contains more silica, thus requiring more lime to remove the phosphorus. Naturally, iron ore high in silica should be avoided. Millscale is particularly useful, during the later stages, for increasing the ferrous oxide content of the slag, since for this purpose iron ore is somewhat too severe. The millscale (or iron ore) which serves, together with the oxidizing gases, to remove most of the carbon should be used only sparingly at first, in order to obviate a sudden carbon reaction when the necessary temperature is reached.

Should the carbon content fall considerably while the phosphorus content is still high, there need be no hesitation in adding the millscale, since the slag will be sufficiently basic to expel much of the remaining phosphorus before the bath goes off the " boil." Normally, by the time sufficient phosphorus has been removed rather too much carbon has been lost, the content being down to 0·3% or less.

While still in the furnace, the steel may be recarburised by adding spiegel (which contains about 5% carbon) or low-silicon pig iron. Similarly, if towards the end of the process the sulphur content is high, spiegel may be added, as a desulphurising agent, up to the amount of manganese required in the finished steel.

So far as recarburising is concerned, it is more usual, however, to add an appropriate amount of pea-sized anthracite as the steel is being tapped into the ladle, allowing for about 20% loss. Heavy additions of anthracite (beyond 0·5% carbon) set up uneven distribution of the carbon, and the experienced steel-maker arrests the carbon content when only slightly lower than that required in the finished steel.

Deoxidizing additions of ferro-silicon are also made. In place of ferro-silicon and ferro-manganese, silico-manganese may be used as a ladle addition. One of the advantages of having kept the manganese content above 0·2% is that little deoxidation is required, so that the total amount of deoxidation products is favourably small.

THE ACID OPEN-HEARTH PROCESS

A higher grade of steel than that produced by the foregoing basic method is made by the much more costly acid open-hearth process, which accounts for about 10% of our total output of steel ingots and for a small proportion of our castings.

In the acid open-hearth process the lining of the furnace, as in the case of the acid electric furnace, is largely silica.

The Charge.—First and foremost, the pig iron used must be low in sulphur and phosphorus, say each 0·035% maximum, since neither is removed. Actually, the contents increase somewhat, owing to absorption of sulphur from the gases and to concentration of the charge due to removal of the other impurities. To minimise sulphur absorption, the gas producer coal must be of a good grade. Most acid steel specifications limit both sulphur and phosphorus contents to a maximum of 0·06% each, and others are even more restrictive.

A fairly high silicon content of the order of 2–3% is required in the pig iron, so as to minimise erosion of the silica lining by the iron oxide formed. Oxidation of silicon to silica also generates a certain amount of heat, but as with the oxidation of the other impurities, is not sufficiently rapid to be of much significance. A rather low manganese content (1% max.) is usual, since manganese leads to a heavy consumption of iron ore and attacks the silica hearth.

Generally, but not always, less pig iron than steel scrap is used, the proportions depending on the type of steel being produced, and being such as to provide an average silicon content of 1% or so, and sufficient carbon to allow of adequate control. Lower average silicon contents would entail a grave risk of over-oxidation, while higher contents would lengthen the interval between melting and boiling.

The hematite ore, which should be lumpy, must be as pure as possible, with sulphur and phosphorus contents preferably below 0·3% each, and for this purpose ore of Cumberland origin is very suitable. It is scarcely possible to calculate the amount of ore required. A 25-ton 1% carbon charge may require 15 cwt. of ore to reduce the carbon to 0·1%.

Refining.—From the beginning of the process, the removal of silicon proceeds well, and manganese also oxidizes readily during the early stages. The first slag formed is a silicate of manganese and iron. Initially, the removal of carbon is slow.

Thus, by the time the charge has completely melted, a good deal of the silicon and manganese, as well as some of the carbon, has been oxidized. The carbon content at the end of the melting period is a function of the proportion of pig iron and scrap steel used, according to the product desired. If mild steel is being made the melted bath may contain 0·6% of carbon, or if a higher carbon steel is sought, 1% or more.

When the charge has completely melted, feeding with hematite ore is commenced. From now on, fracture samples for judging the carbon content are taken periodically from the middle door and as close as possible to the centre of the bath. With diminishing carbon content the fracture passes from a finely crystalline to a fibrous silky appearance and the practised operator can estimate the carbon content to the first place of decimals and beyond.

At the later stages, samples are also sent to the laboratory for carbon content determination by rapid analysis. Specially shaped samples are used where the carbon is to be determined by means of the very useful instrument known as the carbometer.

Feeding with ore first oxidizes any silicon and manganese, and so the first addition produces a violent reaction. This soon dies down and further additions of ore are made periodically. After two or three feeds, practically all the silicon has been oxidized, and then follows oxidation of the carbon, the evolution of carbon monoxide causing the bath to " boil." Once boiling has begun, the carbon is eliminated rather rapidly.

Feeding is now carried out more slowly, say about every 20 minutes, and is stopped when the carbon content is 20–25 points above that required in the finished steel. Carbon elimination is stimulated by rabbling with steel rods or retarded by adding pig iron.

Of paramount importance is the control of temperature which is judged by the eye and by means of the action of the bath on steel bars, while at the later stages, recourse is had to the immersion pyrometer. If the bath becomes too hot, steel scrap may be added. A particularly high

temperature is required where alloys are to be added.

Shortly before the end of the process, when the carbon content is almost down to that required, the slag becomes less fluid, the slag samples being quite glossy. To correct this tendency, a small amount of limestone may be added.

Final Additions.—When the carbon content is as required in the finished steel, a little spiegel and/or ferro-silicon or silico-manganese is added to obviate any further loss, and practically to deoxidize the bath. The charge is then tapped. Should the last analysis show the carbon to be low, a final adjustment may be made by adding anthracite in the ladle. Ladle additions of manganese and silicon may also be made.

When alloy steel scrap is included in the original charge a preliminary analysis is carried out after the bath is completely melted. Alloy additions may be made either in the furnace or in the ladle. It is usual to add nickel, chromium and molybdenum in the furnace and manganese, vanadium and titanium in the ladle.

Rigorous analytical control is not confined to the question of carbon content. Samples of slag are also taken; these are crushed and then analysed, especially for their ferrous oxide content. Very thin slags are undesirable, and may be thickened by additions of ferro-silicon. The consistency of the slag is gauged by means of rod tests.

CHOICE OF PROCESS

In view of the considerable part played by the foregoing processes in the country's economy, it is important that the process selected should provide the best balance of cost and essential quality. It is hoped that the descriptions given will facilitate such a choice, suitably based on service requirements.

The future of the steel castings industry is particularly bright. In many large projects the special characteristics of these castings are being exploited on a new scale, the direct result of marked improvements in manufacture. Only by means of detailed discussion will founder and user derive the fullest benefit, however. Such co-operation will bring to castings added prominence as a feature of the steel age in which we live.

Phosphate Processes for Iron and Steel*

with Special Reference to Rust-proofing

By E. E. Halls

Initially developed to protect iron and steel against corrosion, and still principally used for that purpose, the results of research work with the phosphate processes have greatly increased the scope of their usefulness. In recent years, phosphate treatments have been developed for imparting wear resistance in numerous cases in which metal to metal contact is involved in the functioning of a mechanism. In some instances sheet or strip is phosphatised to assist drawing operations in pressing and to reduce wear on tools. These applications are reviewed and some test results are given.

Some Test Results

To illustrate the claims made in the foregoing, a selection of test results on various types of material or component will be presented.

Table I refers to finishes on hot-rolled black structural steelwork, the base material being received in a heavily scaled and rusty condition. The specimens for test were channel, about $2 \times 1 \times 12$ in. long, and they were cleaned by trichlorethylene degreasing and freed from rust and scale by shot blasting. They were then metallically clean but the surface condition was poor, reflecting the irregular degree of scaling in the original, and being very rough with many prominences. The tabulated data are typical for a range of types of enamel finishes upon this kind of surface with and without further chemical pretreatment. They are arranged in groups of three, the first being finished in the clean condition described without phosphatising, the second included the short-time phosphatising type of processing, and the third the full-time phosphatisation.

The test to which they were subjected consisted of conventional salt spray exposure, in which the specimens were subjected at room temperature to the action of the mist produced by atomising a 20% salt solution with clean moist compressed air. The atomiser was situated at the base of the test cabinet, and the specimens were obliquely arranged on glass shelves which also served to baffle the heavier drops of the spray. The atomiser was operated during the eight-hour day, and the specimens left in the spray laden cabinet overnight. They were rinsed in cold running water and dried on a soft cloth at the start of each day's test.

Samples 1–3 were finished with a single coat of heavy bodied air drying dark grey enamel having a china wood oil base, and allowed to air dry fully for a week before testing. The roughness of the base metal presented a number of "high spots" which in effect were only thinly coated with enamel due to "drain-down" and which, therefore, offered numerous points of weakness to the corroding conditions. This is shown by the rapid rate of deterioration of sample 1, and it is significant to note the much slower rate of corrosion of sample 2, and that this is due to the short-time phosphatising treatment. It is even more significant to observe the very much superior performance of sample 3 with its full-time phosphatised coating.

Samples 4, 5 and 6, having two coats of the same enamel finish naturally show better performance than the first three specimens, with the same marked improvement due to the short-time phosphatising, and still more marked superiority due to the full-time processing.

Similarly, samples 7, 8 and 9 two coat air dried finishes, show the value of a red-oxide primer as a rust inhibiting first coating—i.e., sample 7 is much superior to sample 4, and 8 and 9 exhibit greater durability than 5 and 6, respectively.

* Concluded from Page 168, July issue.

TABLE I.—STRUCTURAL STEELWORK (HOT ROLLED BLACK IRON), SHOT BLASTED AND FINISHED—RESULTS OF EXPOSURE TO SALT SPRAY TESTS

Sample No.	Type of Phosphate Treatment	Total No. of Organic Coats	Nature of Organic Coats	Time Period in Days under Salt Spray for Deterioration to :—				
				First signs of Rusting	Slight Rusting	Fairly Heavy Rusting	Heavy Rusting	Very Heavy Rusting
1	None.	One.	Air-drying oil enamel.	1	1	2	3	4
2	Short Time.	One.	Air-drying oil enamel.	2	4	17	21	25
3	Full Time.	One.	Air-drying oil enamel.	14	14	140	—	—
4	None.	Two.	Air-drying oil enamel.	2	3	17	21	40
5	Short Time.	Two.	Air-drying oil enamel.	21	42	140	—	—
6	Full Time.	Two.	Air-drying oil enamel.	21	140	—	—	—
7	None.	Two.	Red oxide primer and air-drying oil enamel.	21	24	42	70	140
8	Short Time.	Two.	Red oxide primer and air-drying oil enamel.	24	140	—	—	—
9	Full Time.	Two.	Red oxide primer and air-drying oil enamel.	140	—	—	—	—
10	None.	Three.	Red oxide primer, surfacer and air-drying oil enamel.	21	24	140	—	—
11	Short Time.	Three.	Red oxide primer, surfacer and air-drying oil enamel.	140	—	—	—	—
12	Full Time.	Three.	Red oxide primer, surfacer and air-drying oil enamel.	140	—	—	—	—
13	None.	Two.	Stoved red-oxide primer and stoved enamel.	21	24	70	140	—
14	Short Time.	Two.	Stoved red-oxide primer and stoved enamel.	21	24	Greater than 140	—	—
15	Full Time.	Two.	Stoved red-oxide primer and stoved enamel.	70	Greater than 140	—	—	—
16	None.	Two.	Stoved zinc chromate primer and stoved enamel.	21	140	—	—	—
17	Short Time.	Two.	Stoved zinc chromate primer and stoved enamel.	21	Greater than 140	—	—	—
18	Full Time.	Two.	Stoved zinc chromate primer and stoved enamel.	42	Greater than 140	—	—	—

Again, samples 10, 11 and 12 are three coat air dried finishes in which the intermediate layer is a surfacer. The benefit from the smoothing action of the latter is self evident in all three specimens. On the remainder of the specimens are stoved finishes, and on specimens 13, 14 and 15 they comprise a primary coat of red-oxide primer and a finishing coat of oil-modified alkyd synthetic enamel. They show the same relative behaviour as the other groups, although peculiarly the performance of 13 is superior to 5, whereas 14 and 15 are a little inferior to 6 and 7. Finally, specimens 16, 17 and 18, two coat stoved finishes, have a first coat of yellow zinc chromate primer, which has high qualities of rust inhibition. This is clearly demonstrated by the outstanding performance of this group of specimens.

It will be seen throughout the series that while the number of coats, surfacing and nature of the primer, all influence the durability of the finish in no uncertain manner, the phosphate treatment, short or full time, makes an invaluable and infallible contribution to the serviceability of the finish.

Table II deals with finished assemblies under salt spray test. The assemblies were all mild steel, being shells consisting of three components, formed or shaped from 0·024 in. thick furniture steel, spot welded together and stiffened along two sides by spot welded steel strips. The specimens thus presented not only internal and external surfaces with sharp corners, but also seams and overlaps. They were tested with and without phosphate treatment, plus one and two coats of stoved finish. All the phosphate treatments were short period type. The tabulated data are mainly self-explanatory.

Sample 1, one coat finish without chemical pretreatment, is revealed as very poor, the enamel quickly losing adhesion and flaking and peeling. In contrast, the phosphatised sample 2 withstood about 10 weeks of the test before starting to fail on general surfaces, and its enamel coating was still firmly bonded at the end of 15 weeks. Sample 2, therefore, represents a serviceable finish.

Sample 3, without phosphate treatment, shows that increasing the finish thickness by two coats of enamel naturally delays the general rusting somewhat, but the loss of adhesion is still apparent, and serviceability must be deemed poor. Sample 4 on the other hand, two enamel coats on phosphatisation, exhibits a really reliable performance. Samples 5 and 6 show the added benefit from the use of a red-oxide rust inhibitive primer, and Nos. 7 and 8 that obtained with a zinc chromate type of primer.

The conclusions drawn from the information in Table II are that the phosphate treatment ensures adhesion and retention of adhesion in a degree out of all comparison with that given by special primers, it gives a useful life to one coat finishes, it fulfils the role of a rust inhibitive primer, and, in conjunction with the latter, it augments the rust inhibition.

Table III briefly characterises the organic finishing media employed on all the specimens ; all were applied by spray in the conventional manner.

From the foregoing, it is evident that phosphate treatments are a sound pretreatment for iron and steel, and that they are indispensible for trouble-free organic finishing where a robust finish is required. For heavy structural iron work, the full-time phosphate processes have some advantages, particularly in reducing the number of enamel coats that are necessary. For " clean " metal or steel of good surface, the short-time processes are generally adequate. The merits of the phosphate finishes are particularly borne out in the finishing of a miscellany of components, including those with seams and overlaps, as from resistance welding, those with many perforations, holes or bends, and those embodying moving elements such as hinges.

Phosphatised Sheet as a Substitute for Tin-plate

It is interesting to note that steel sheet, phosphatised and lacquered, was extensively investigated in Germany as a substitute for tin-plate for food cans. The work dates back at least to 1937, and it embraced the establishment of the best base material, the most suitable phosphate coating, appropriate lacquers, and production methods, including the butt-welding of the side seam and bottom. It is understood that production was

TABLE II.—SHEET STEEL ASSEMBLIES, SPOT WELDED, WITH AND WITHOUT PHOSPHATE TREATMENT (SHORT TIME), ENAMELLED AND EXPOSED TO SALT SPRAY
TEST CONDITIONS—PROGRESS OF DETERIORATION

Sample No.	Chemical Pre-Treatment	Total Number of Organic Coats	Nature of Organic Coats	Condition after Exposure to Salt Spray for Test Period of Weeks :—					
				0·5	1	3	6	10	15
1	None.	One.	Stoved Synthetic Enamel.	Rusting along seams & edges. Blistering and flaking of enamel from seams & edges.	Extensive flaking of enamel and heavy rusting. Condition poor.	—	—	—	—
2	Phosphate.	One.	Stoved Synthetic Enamel.	Some rusting at edges. No blistering or flaking of enamel.	No further change.	Marked rusting along seams and edges.	A few rust spots on general surfaces.	A few patches of rust on general surfaces.	General rutting in spots and patches. Enamel blistering from seams & edges, but no general failure of enamel.
3	None.	Two.	Stoved Synthetic Enamel.	Rusting along seams & edges.	Rusting at seams and edges fairly heavy, and enamel blistering at these points.	Adhesion of enamel now very poor; flaking from seams & edges.	Rusting now very heavy, and flaking of enamel general. Condition poor.	—	—
4	Phosphate.	Two.	Stoved Synthetic Enamel.	Unaffected.	Unaffected.	Rust forming at seams.	Rusting general at seams & edges.	No further change.	Blistering of enamel & rusting confined to edges. General finish unaffected. adhesion excellent.
5	None.	Two.	Stoved Red Oxide Primer and Stoved Synthetic Enamel.	Unaffected.	Unaffected.	Traces of rust at seams and edges.	Enamel blistering at edges and seams.	Slight spread of rust and of blistering from seams & edges.	Little further deterioration, general surfaces still very good. Enamel adhesion good but inferior to sample Nos. 2, 4, 6 and 8.
6	Phosphate.	Two.	Stoved Red Oxide Primer and Stoved Synthetic Enamel.	Unaffected.	Unaffected.	Unaffected.	Traces of rust in seams and on edges.	Little further change.	Little further change, finish in excellent condition.
7	None.	Two.	Stoved Zinc Chromate Primer and Stoved Synthetic.	Unaffected.	Unaffected.	Unaffected.	A little rusting at seams and edges.	No change.	No change. Finish very good, enamel adhesion very good but inferior to Nos. 2, 4, 6 and 8.
8	Phosphate.	Two.	Stoved Zinc Chromate Primer and Stoved Synthetic.	Unaffected.	Unaffected.	Unaffected.	Traces of rust at seams and edges.	No change.	Little further change. Finish excellent.

TABLE III.—CHARACTERISTICS OF FINISHING MEDIA EMPLOYED FOR CORROSION TEST SPECIMENS

	Air-drying Media			Stoving Media		
	Red Oxide Primer	Grey Surfacer	Finishing Enamel	Red Oxide Primer	Zinc Chromate Primer	Finishing Enamel
Drying time before application of next coat in hours ..	4	4	8	—	—	—
Stoving time at 250°/260° F. hours	—	—	—	½	½	½
Compositional						
Volatile Spirit (loss in weight, 3 hours at 110° C.). %	42·5	34·7	41·2	30·3	58·4	55·5
Total Solids %	57·5	65·3	58·8	69·7	41·6	44·5
	100·0	100·0	100·0	100·0	100·0	100·0
Physical						
Viscosity at 25° C. centipoises	400	650	720	540	420	600
Specific gravity at 25° C.	1·42	1·83	1·08	1·55	1·51	1·12

Thinning to spraying consistency with Coal Tar Solvent Naphtha in All Cases

achieved in a large way, except for cans for the more acid fruits, and that the side seams were welded, the tops and bottoms being beaded and folded. The "Bonderising" processes (proprietary name) were used as the basis because they lent themselves to modification and control to give the desired thickness of coating and grain size. Cold-rolled mild steel sheet was adopted as the base metal, the "Bonder 5" process with 5 minute treatment was used for phosphatising and a phenolic or alkyd resin lacquer was preferred. The latter was selected to give a continuous film and complete coverage in a thickness of 8–10 grams (dry film substance) per sq. metre. Tests employed in the investigation include 3% salt spray for extended periods, and autoclave tests at 120° C. with the specimens in 0·5% lactic acid and 3% brine solutions. The phosphate coating was found to ensure resistance to rupture of the lacquer film as well as its adhesion, and these results could not be obtained with plain or sanded metal. Further, the degree of corrosion or solubility of the iron was appreciably reduced. The finished cans were tested by filling with various foods and sealing in the normal manner, and then maintaining at a temperature of 37° C. for a year. For certain foods—i.e., spinach, asparagus, and fish in oil, the lacquered phosphatised cans were claimed on test to withstand the conditions better than tin-plate. For fruit they were not so good, and this limitation in the canning of very acid fruit had to be recognised.

Phosphate Coatings for Wear Resistance

Mention must be made of another specific application for phosphate coatings on sheet stock or on components concerning wear resistance. Thus in deep drawing, the treatment of the sheet stock, or of the intermediate component in the " blank and cup " stage, can enable a more severe pressing operation to be performed without rupture of the material. This is a function of the capacity of the crystalline phosphate coating to retain the lubricant, and of its role in preventing metal to metal contact between work and tool. Patents cover the use of phosphate coatings in this application and in similar cases where wear resistance is involved (e.g., B.P.455077, due to F. Singer, 1936).

Because the development in this field, as described by R. E. Shaw,* is deemed to be a momentous one of which more practical notice should be taken, the following abstract and notes are taken from this source.

After briefly tracing the history and developments of phosphatisation processes from the time of the Coslett patents in 1906, through to the modern iron, manganese and zinc phosphate complexes, Shaw points to 1936, when the Singer patent appeared, as marking the new field of application. This patent claimed that the phosphatising of material or parts prior to drawing or pressing resulted in markedly less wear upon the dies and a smaller power consumption. This application was successful and the preferred phosphate coatings were the iron-manganese composition. The success of the procedure is stated to be due to the non-metallic layer of metal phosphate, which is tenaciously adherent to the material, active as a parting layer between metal and tool. The crystals of this coating change under the extreme pressure imposed to yield a glassy transparent layer. This is effective in preventing scoring of the tools and pick-up of metal, thereby prolonging the life of the die. During the war, the phosphate chemicals used for this purpose in Germany is stated to have been greater than twice the quantity used for all other purposes together.

B.P.512,594, due to the American Chemical Paint Co., in 1937 marked a further advance by using phosphate coatings for the prevention of wear of metal parts subjected to sliding friction. Zinc phosphate coatings are suitable for this purpose, although again, the iron-manganese combination is preferred as the most effective. W. H. Spencer† describes the production use of the latter for the treatment of automobile rings. A typical series of process operations is cited as :—

1. Degrease in trichlorethylene, or in mild alkali followed by water wash.
2. Phosphatise (iron-manganese phosphate composition) by immersion for 10–15 mins. at 210° F.
3. Rinse in warm water at 140° F. for 1 minute.
4. Rinse in warm soluble oil at 180° F. for 1 minute.
5. Drain and allow to dry.

The process is controlled by periodic alkalimetry test as already described. For treatment, automobile rings are jigged in a simple manner by racking loosely on mild-steel rods which have a diameter a little larger than the gap of the ring. The high output possible is indicated by the figure of 2,000 rings/hour from a phosphatising tank of 60 gallon capacity. Small parts not readily adaptable to jigging are treated in woven wire baskets, and flat parts that tend to lay together can be treated in barrel plants of the rotary drum construction. Steam or gas heating may be employed, and the maintenance involved is the periodic addition of make up chemicals, and infrequent removal of sludge from the bath. The processing causes the iron surfaces of the work to react with the acid phosphate chemicals, during which period vigorous gassing occurs, gradually subsiding as the surface of the work becomes converted to an adherent, crystalline layer of complex iron-manganese phosphates. The thickness of the metal increases during the process, which is virtually complete in 10–15 minutes. Control of the crystal size of the layer can be controlled within limits by variations in the process operating conditions, but generally a finely crystalline texture, quite smooth and soft to the touch, is desired. The process is applicable to cast iron, mild steel and most ferrous alloys, with high chrome and stainless steels the notable exceptions. The stopping off of local areas with lacquer is feasible.

Pretreatment influences the physical condition of the coating. Coarsely crystalline textures result if the work is cleaned in strongly alkaline degreasers, and this should be avoided. Pickling to remove rust may give the same effect, so, therefore, light abrasive blast is preferred when rust or scale has to be removed. These phenomena are no doubt due to " etching " of the grain boundaries in the base metal, and the resulting pattern dictates the mode of formation of the phosphate coating. The iron-manganese phosphate solution itself is stated to cause a preferential pitting of the iron surface to a depth of about 0·2 mils., and simultaneously to build up a coating of 0·4 mils., so that the result is a thickness increase per surface of the order of 0·2–0·3 mils. For wearing parts, this is regarded as a bedding-in layer, and the wear upon running-in is usually slightly greater, so that it is not generally necessary to make an allowance for the phosphate layer thickness.

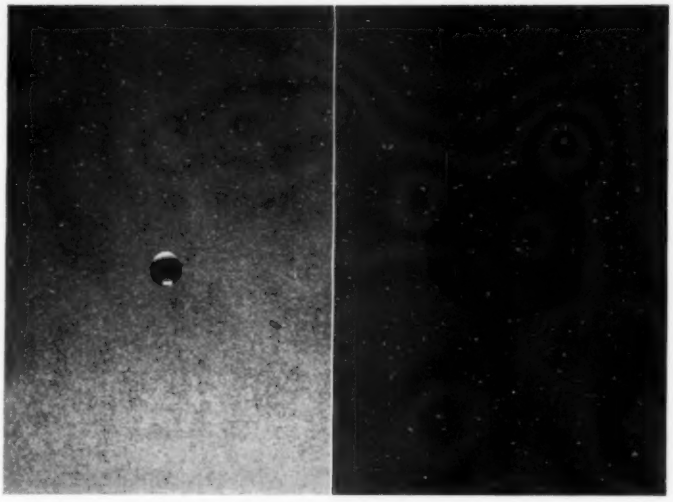
" Scuffing " is a serious trouble in modern engines in which higher loads and speeds, involving more lubrication troubles, are demanded. Wear under " Scuffing " conditions is shown by test to do more damage to surfaces in a few hours than does normal running over several years. The tendency to local seizing and welding of sliding surfaces causes tearing of the surfaces very rapidly. Damage of the surfaces makes lubrication more difficult and harm progressively increases. To meet this condition, the requirement is a surface treatment that will retain lubricant and that will withstand very high bearing loads without failure of the film. Lubricant alone cannot fulfil this function. The iron-manganese phosphate coatings approach this ideal, in conjunction with lubricant of course, and have proved to be the most successful solution to the problem to date. The success of the treatment on piston rings, tappets, gears and the like, is accounted for by the ability of the coating to withstand, in effect, poor conditions of lubrication without scoring of the surfaces.

Shaw cites M. O. Teetor‡ in propounding the following explanation of the performance of phosphate coatings in this direction. High temperatures are created at local points where the film of lubricant is ruptured, and temperatures of 650° C. are predicted from the loca

* " The Phosphate Treatment of Wearing Parts of Machinery," by R. E. Shaw; paper presented before The Institute of Marine Engineers, Jan. 4, 1947, and reproduced in *The British Chemical Digest*, Vol. 1, No. 4, Jan., 1947.
The illustrations associated with the present abstract are reproduced by courtesy of Mr. R. E. Shaw to whom the author and editor express their thanks.

† *S.A.E. Jour.*, 1937, **41**, 495.

‡ *S.A.E. Jour.*, 1938, **42**, 137.



Untreated Treated

Fig. 1.—Showing the spread of a drop of oil on a phosphated surface.

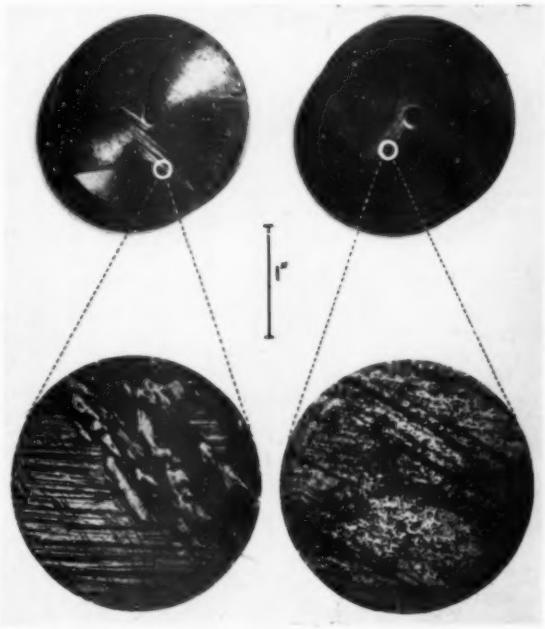
formation of iron carbide. Plastic flow occurs with melting taking place, and sulphur and phosphorus impurities give lower melting compounds which assist this. The phosphate coating holds the lubricant at these high spots and minimises the possibility of welding. During running-in, the high spots do become polished but without scoring or pick-up, and the polishing gradually extends to about 50% of the surface area. The phosphate coating remains in the depressions and holds a reservoir of lubricant, and an ideal bearing surface is presented. The coating after running-in, has a transparent, glassy, burnished appearance.

Other advantages of the phosphate treated parts are, in some cases, the use of a thinner and less expensive lubricant and a degree of rust proofing in storage and in service.

Fig. 1 shows the rapid and complete spread of a drop of oil on a phosphated surface, and the negligible spread on an untreated surface. The oil used was medium viscosity and the specimens were photographed 15 minutes after the application of the oil. Again, by dipping and draining, it was found that the phosphated surface held 770 mgms./sq. ft. of oil against only 155 mgms. for the untreated sample. After wiping with cotton wool, the 770 mgms. became reduced to 300 mgms., which is still twice that on the unwiped non-phosphated specimen. Apart from the all-important lubricant retaining property, the value of the non-metallic phosphate layer in preventing welding and scoring must not be overlooked. Colloidal graphite and extreme pressure lubricants are also successful on the phosphate treated surfaces.

Shaw calls attention to the thorough investigation of gear scuffing by the Research Department of the Institute of Automobile Engineers, of H. D. Mansion, Institute of Automobile Engineers Res. Report No. 1943/15 under the title of "The Effect of Chemical Surface Treatments on the Scuffing of Gears." A range of electroplate, chemical etching and phosphate processes were studied with the conclusion that the phosphate treatments were the most efficaceous for the prevention of scuffing on gears. The treatment containing manganese phosphate provided the greatest degree of protection and caused the load to produce scuffing to be doubled, and the protective value was still maintained after running for 100 hours at 80% of the load required to produce scuffiing in untreated gears. The amount of wear in this 100 hours was slightly greater than the coating thickness, but no greater than a few ten-thousandths of an inch—i.e., the gears were still within the original machining limits. The zinc phosphate treatments were only half as effective as the manganese type, and raised the scuffing load 50% above that for untreated gears, but this type did not retain anti-scuffing properties to the same extent after running-in. The build-up of the zinc phosphate coatings is stated to be very slight, only of the order of 0·05–0·1 mils., and therefore they are advantageous where machining limits are unusually close.

A peculiar practical feature is cited and should be observed closely. It concerns



Untreated. Treated.

Fig. 2.—Show the superior performance of phosphated tappets under conditions of severe wear.

the difference in performance of phosphated piston rings on poppet-valve and sleeve-valve engines, respectively. With the former, phosphated on all surfaces, satisfactory performance over many years of service is recorded with both aluminium and cast iron pistons. With sleeve-valve engines, piston groove wear resulted, and this is explained by the greater relative movement between ring and piston, this causing a lapping action in which the aluminium alloy piston suffered most. This was overcome by processing the rings in batches clamped face to face so that treatment was restricted to outer surfaces only.

Alternatively, an allowance was made to grind the flat-surfaces after treatment.

Tappets are shown in Fig. 2 to demonstrate the superior performance of the phosphated surfaces under conditions of severe wear. The photographs at × 80 show the scoring on the untreated surface, but dark areas of original phosphate coating on a generally mottled surface, despite the obvious excessive loading at this point, on the treated surface.

Surface graphs are given in Fig. 3 for these tappet faces. They were taken on a "Talysurf" meter with a vertical magnification of 20,000 and a horizontal magnification of 200. The top photograph is the normal untreated ground surface. On this same scale, the unused phosphated surface would show its crystalline structure with peaks and valleys extending off the page. The centre curve is an ideal bearing surface, being the phosphated one run-in at light loading. In this, crystals have merged into a flattened surface with depressions in which oil can be held. The third or bottom curve is the same after heavy loading, showing a more flattened condition of the same character as the lightly loaded surface.

Practical observations show that the phosphate coating is not one that is brittle and completely removed in a short time, and they indicate that the mechanism of running-in has the following effect upon the coating. In the initial stages, the sliding motion is essentially a polishing one, during which process the crystal structure is broken down. Consequently, high spots become flattened, and depressions tend to become filled, and the coating acquires its glassy transparent appearance in distinct contrast to its original character. Microscopic examination of a just run-in surface reveals about 50% of the area as bright spots and the other 50% as dark depressions consisting of relatively unchanged phosphate layer saturated with oil. This surface retains its original scuffing resistance and is superior to other prepared surfaces. It is this retention of scuffing quality which is the factor of first importance.

Surface photo-micrographs are reproduced in Fig. 4. The left picture A is typical of the crystalline phosphate treated surface. The centre illustration B is the same surface run-in at light loading, and it shows the bright areas, fairly uniformly distributed in a dark back ground of phosphate layer. The right illustration C is after a further stage of running-in, with the bright spots

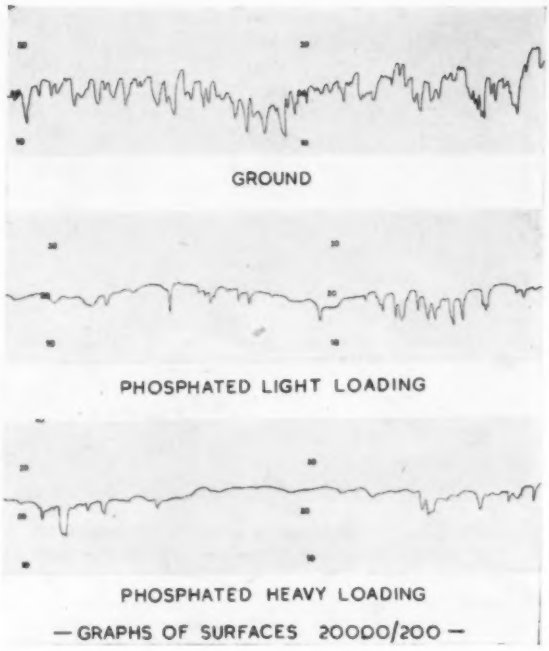
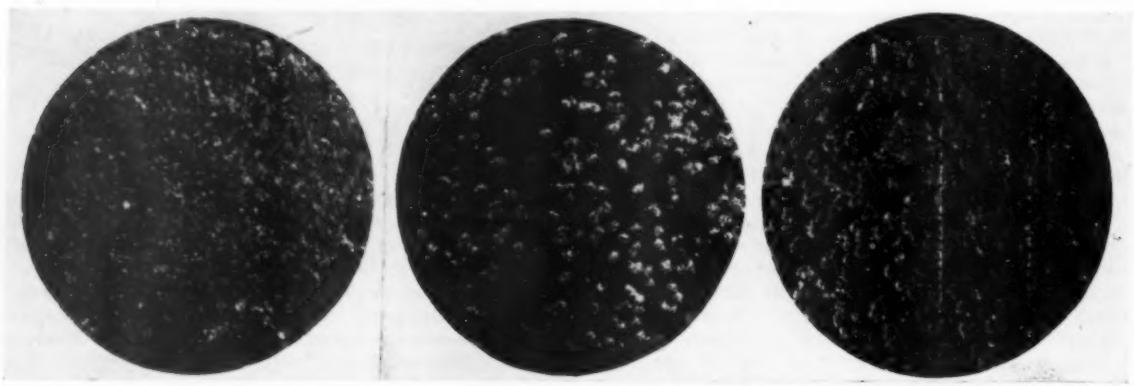


Fig. 3.—Surface graphs for the tappet faces.

extended and merging into the background of phosphate layer, but still with much of the latter in evidence.

Although the application has by no means been fully explored, phosphate treatment has, in the restricted applications given, solved the problem of fretting corrosion, for the nature and cause of which Shaw refers to Tomlinson, Thorpe and Gough's paper.** Shaw briefly summarises the subject, explaining fretting corrosion as that which may occur when closely fitting surfaces are subjected to very small alternating movements, and that it is generally due to the effects of vibration. The first visible signs of this trouble with steel surfaces may be the seepage of rusty oil from the parts, and close examination of the latter reveals pitting and irregular corrosion. Considerable transfer of metal

** "An Investigation of the Fretting Corrosion of Closely Fitting Surfaces," *Proc. Inst. Mech. E.*, 1939, **411**, 223.



A B C

Fig. 4.—Photomicrographs of phosphate treated surfaces; B and C showing running-in spots.

may occur, and roughening as though local seizing has occurred. Attrition on a molecular scale leading to the formation of finely divided readily oxidised particles has been stated to be the cause of the "cocoa"-like rust formation. Once thought to be the result of a chemical process, it is now considered to be a mechanical effect, the first stage being mechanical and the final chemical oxidation. The fretting tends to increase with improvement in surface finish and tightness of fit, so that it cannot be eliminated by improvement in contact in these senses, yet on the other hand rougher or looser fits cannot be adopted for obvious reasons. Plated surface coatings of copper, silver, and chromium, and cast-on cadmium-nickel alloy, gave no solution to the problem, and all promoted metal transfer. On the other hand, phosphate coatings proved to be satisfactory. Further, they had the advantage of simplicity in application and no interference with dimensions, whereas metal coatings needed machining to size.

In these applications, protection against wear is the primary objective of the phosphate coatings with protection against corrosion of secondary importance. In the more widely known application to metal finishing, protection against corrosion is the primary objective. Yet incidentally, wear resistance is a secondary factor in this field because it is noted that enamel finishes on phosphate coated surfaces have tenacious resistance to wear when without the phosphate coating the same finish will fail very quickly. It is evident, therefore, that these apparently diverse applications are not so far apart as would be thought at first sight.

The Dislocation Theory of Slip

Recent Developments in Britain

By F. R. N. Nabarro

Royal Society Warren Research Fellow, Bristol.

Each day sees the addition of some fresh item to our fund of empirical metallurgical knowledge. At the same time, the workers in the field of metal physics are gradually building up a picture of the fundamental nature of metals and alloys, in an attempt to establish the laws governing their behaviour. In this paper, which was presented before a meeting of the D.G.M. in Stuttgart, the author outlines the three main Briish developments of the dislocation theory of slip.

THE three main developments of the dislocation theory of slip in Britain during the last few years have been the attempt to derive a theory of slip on an atomic basis by Mott and others in Bristol, the study of the bubble model of a metal by Bragg, Nye and Lomer in Cambridge, and the investigation of the interaction between dislocations and dissolved atoms by Cottrell and his collaborators in Birmingham. Much of this work is summarised in the report of the 1947 Bristol Conference on the Strength of Solids,[1] and in an article by Cottrell in "Recent Advances in Metal Physics."[2]

The Movement of Dislocations

The theories developed in England differ from those commonly discussed in Germany[3] and France[4] by assuming that there are always dislocations present in a crystal, and that the strength of a crystal is the least stress under which the dislocations can move across the crystal. The recent developments of this theory have grown from the idea that a dislocation is not a single displaced atom or a row of displaced atoms lying on a straight line, but is a flexible line of disturbed atoms passing through the crystal.

We start with the idea of an edge dislocation, such as is produced when the upper part of a crystal begins to slide over the lower part (Fig. 1). If slip starts at a point T on one side of the crystal, and has not yet reached the other end T′ of the slip plane, there must be a region AA′ in the glide plane where n atoms below the glide plane are associated with n ± 1 atoms above the glide plane. This disturbed region AA′, which appears in all planes parallel to the plane of the paper, is called an edge dislocation. An edge dislocation is thus a straight line lying in the slip plane, and perpendicular to the slip direction.

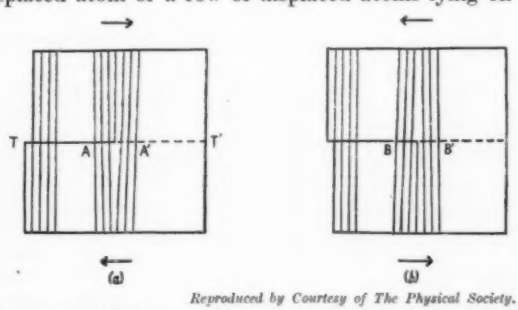


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Fig. 1.—Positive and negative edge dislocations. The crystal above TA has slipped by one atomic distance, the crystal above A′T′ has not yet slipped.

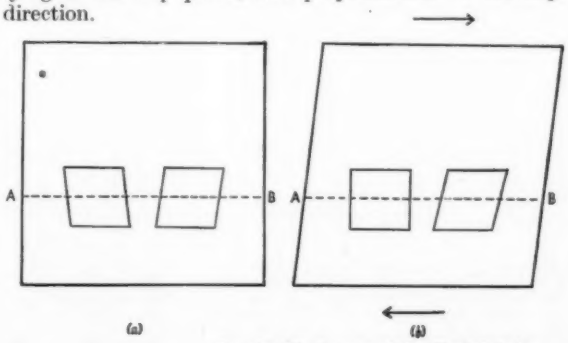

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Fig. 2.—Hardening by internal strains. Internal strains have distorted square regions of the lattice into the parallelograms of Fig. 2(a). A dislocation cannot move from A to B until the external shear stress has strained the crystal to the form of Fig. 2(b).

The simple strain theory of hardening is illustrated by Fig. 2, which represents a section cut out of a crystal having cubic symmetry by planes parallel to the cubic

planes. In Fig. 2a a very small shear stress is applied to the crystal, so that slip starts at a point A and, in the perfect crystal, would propagate across the glide plane to B. Because of internal stresses, the lattice near certain parts of the glide plane is distorted, regions which were square in the unstrained lattice being distorted into the small parallelograms shown. When the dislocation travelling from A reaches the first parallelogram, it is in a region where the local strain is increased if the crystal continues to slip, and the motion stops. The dislocation will travel right across the glide plane from A to B only if the external stress reaches the value shown in Fig. 2b, where the strain at all parts of the glide plane is in the same direction as the applied stress.

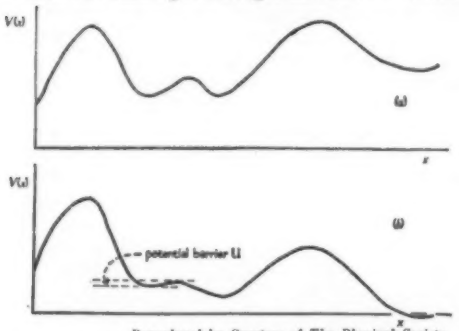

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Fig. 3.—Potential energy V of a dislocation as a function of its position x. Upper curve : no external stress. Lower curve : after application of stress.

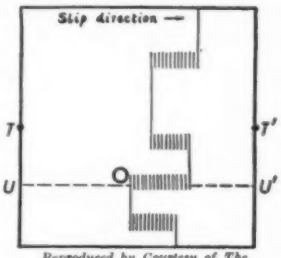

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Fig. 4.—The dislocation of Fig. 1 (a), viewed normal to the glide plane. Continuous lines are segments of edge dislocations, broken lines are screw dislocations.

In the quantitative development of the theory it is convenient to think of the external stress as exerting a force F on unit length of the dislocation, tending to drive it across the slip plane. Let the stress be σ, the length of the dislocation p, the length of the glide path(AB in Fig. 2) q, while the distance by which the crystal slips when the dislocation travels across from A to B is a. Then the forces applied to the upper and lower faces of the crystal are σpq, and the work they do when the dislocation moves from A to B is σpqa. Equating this to the work done by a force Fp acting through a distance q we obtain

$$F = \sigma a \qquad (1)$$

This leads at once to the idea of the potential energy of a dislocation at a given point of the lattice. If the distance the dislocation has moved across the glide plane is x its potential energy per unit length $V(x)$ in a lattice containing internal strains is given by a wavy curve such as the upper curve in Fig. 3. An external stress adds to this a linear term $-\sigma a x$; the resultant is given by the lower curve in Fig. 3. In equilibrium, dislocations lie in the minima of the potential energy curves. The external stress shifts these minima, so that the dislocation moves, and there is a reversible strain greater than the elastic strain in a perfect crystal.[5] The potential barrier U which the dislocation must overcome before it can reach its next position of equilibrium is reduced. If σ_0 is the applied stress at which the barrier would disappear, it can easily be shown that

$$U = \text{const.}\ (\sigma_0 - \sigma)^{\frac{3}{2}}. \qquad (2)$$

At temperature T, this activation energy will be supplied by thermal vibrations at a rate proportional to $\exp(-U/kT)$, and this is a measure of the rate at which dislocations move through the lattice. The rate of plastic flow s is therefore given by a formula of the type

$$s = A \exp[-B(\sigma_0 - \sigma)^{\frac{3}{2}}/kT]. \qquad (3)$$

In this way we obtain a modified version of the Becker-Orowan theory.

We next observe that the strains of Fig. 2 are not likely to have the same distribution in all planes parallel to that of the paper. If the dislocation is a straight line perpendicular to the paper, some parts of it will lie in regions where the internal stress opposes the external stress, and some in regions where the two work in the same direction. In this case, the total force exerted by the internal stresses on the dislocation is much smaller than it would be if the stress distribution were the same in all planes. However, we shall show that in most important cases the dislocation does not remain straight. Where the internal stress opposes its motion, it lags, and where the internal stress is favourable, it moves ahead in the glide plane. We may look on Fig. 3 as a section through a surface which represents the potential energy of a short length of a dislocation as a function

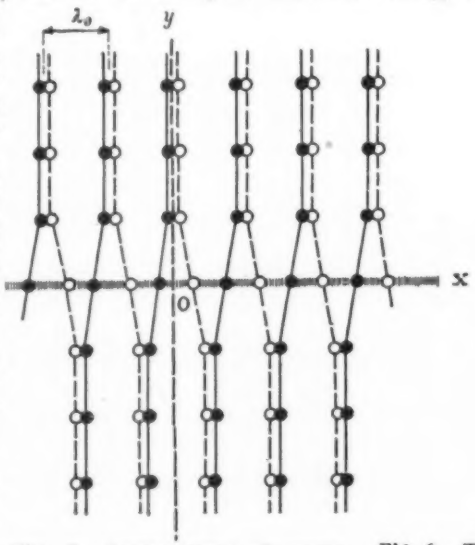

Fig 5.—Arrangement of atoms above (●) and below (○) the glide plane of a screw dislocation (after Burgers).

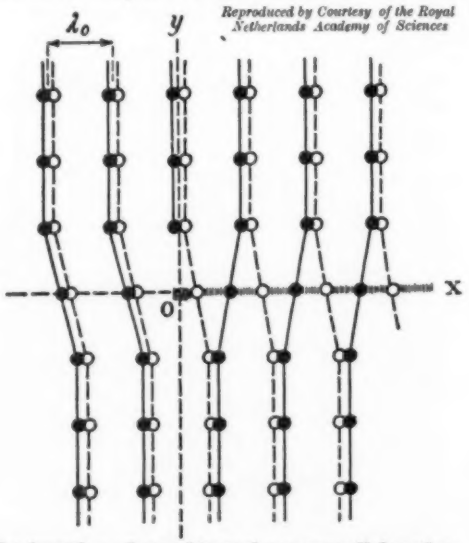

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Fig. 6.—The junction of an edge and a screw dislocation (after Burgers). Atoms above the plane of the figure ●. Atoms below the plane ○. This represents a section of Fig. 4 parallel to that of Fig. 1, but passing through the line UOU'.

of its position in the glide plane. If the dislocation is sufficiently flexible, it lies in equilibrium in the bottoms of the valleys in this surface. Looking down on the glide plane of Fig. 1, the dislocation will appear schematically as in Fig. 4. The parts of the dislocation represented by single lines are edge dislocations such as we have already considered. The parts represented by broken lines are screw dislocations of the type introduced into plasticity theory by J. M. Burgers.[6] Whereas the line of an edge dislocation is perpendicular to the slip direction, a screw dislocation is a line parallel to the slip direction which separates regions of the glide plane over which slip has already occurred from regions which have not yet slipped. Fig. 5 shows the displacement of atoms above and below the slip plane in the neighbourhood of a screw dislocation. Although we have associ-

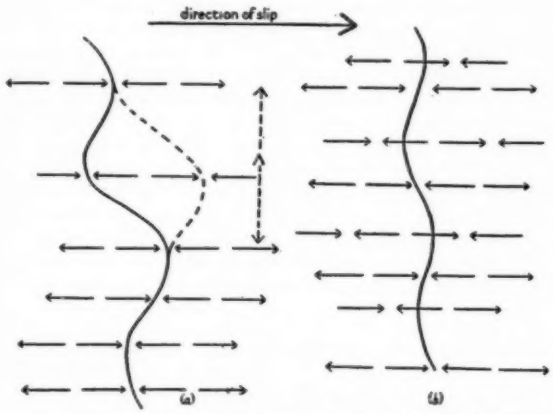

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Fig. 7.—Dislocations acted on by internal stresses which tend to move them in the directions of the arrows. In Fig 7(a), the scale Λ of the internal stresses is large, and the dislocation yields to the stresses. In Fig. 7(b), Λ is small, and the dislocation deviates only slightly from a straight line.

ated a screw dislocation with an edge dislocation lying in a particular glide plane, the screw dislocation can move in any plane passing through its axis, and its sections by all of these planes are similar. For example, Figs. 4 and 5 show the section of a screw dislocation by a plane passing through TT′ of Figs. 1 and 4, and perpendicular to the plane of Fig. 1. Suppose we now take a section parallel to that of Fig. 1, and passing, not through TT′ of Fig. 4, but through UOU′. Then (Fig. 6) the section OU′ of the screw dislocation appears as in Fig. 5. At O we have slight distortion of the lattice without any dislocation below the plane of the figure, and an edge dislocation in planes above that of the figure. We have here an example of the general rule that a dislocation cannot end in the crystal. Its segments of edge, screw or mixed type must extend continuously from one boundary to the other, or else form closed loops. By a segment of mixed type is meant one which lies neither perpendicular nor parallel to the slip direction. Introducing these, we see that a dislocation need not form a rectangular zig-zag as in Fig. 4, but may follow any smooth curve in the glide plane. The geometry of dislocations has been developed by Frank.[7]

The behaviour of a dislocation is in many ways the one-dimensional analogue of that of a soap film. The dislocation has a potential energy per unit length T (corresponding to the surface tension of the film) given approximately by

$$T = \mu a^2, \tag{4}$$

where μ is the shear modulus of the material. This tension causes it to maintain as straight a form as possible. Stresses exert on it a force per unit length given by (1), and these can bend it into curves of radius ρ given by

$$F = T/\rho$$

or

$$\rho = \mu a/\sigma \tag{5}$$

Suppose now that the internal stresses are of magnitude σ_i, and vary from place to place in the lattice in such a way that the sign of the stress changes once on moving a distance $\frac{1}{2}\Lambda$ through the lattice. We call Λ the average wavelength of the internal stresses. We do not believe that the change in stress in the neighbourhood of a dislocation produced by applying an external stress σ will differ from σ by a large factor, and therefore identify σ_i with σ_o, the critical stress of equations (2) and (3). There are now two limiting cases, in which Λ is much greater or much less than $\mu a/\sigma_i$, the radius of the sharpest curve into which the internal stresses can bend the dislocation. The first case, which applies to most work- and precipitation-hardened materials, is illustrated in Fig. 7a, where the arrows represent the direction in which the internal stress drives a dislocation. The dislocation is able to yield to the stress almost everywhere, and lies in the valleys of the potential surface. The other limiting case is illustrated in Fig. 7b, and discussed more fully in the section on solid solutions and precipitation hardening. Here the internal stresses are not large enough to bend the dislocation into curves of radius as small as Λ, and the dislocation is deviated only slightly from a straight track. The intermediate case, for which Λ/a is approximately equal to μ/σ_i corresponds to critical dispersion in precipitation hardening. For well-hardened material, both quantities usually have values of the order of 100.

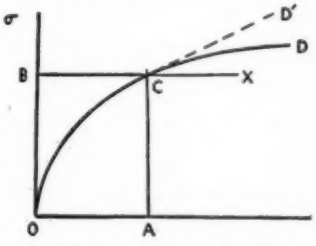

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Fig. 8.—Typical stress-strain curve. At the point C the load is held constant and the specimen creeps.

We can now form an estimate of the activation energy to move a dislocation. In the case of Fig. 7a, the typical glide process will be the motion of a single loop of a dislocation over a potential hill, as shown by the dotted curve. The force on this loop of length $\frac{1}{2}\Lambda$ is of order $\frac{1}{2}\sigma_i a\Lambda$, and this force acts through a distance $\frac{1}{2}\Lambda$ from the bottom to the top of the hump. The activation energy is thus of order $\frac{1}{4}\sigma_i a\Lambda^2$. An external stress reduces this, as in the Becker-Orowan theory.

Transient Creep

A first outline of the theory of transient creep was given by Orowan.[8] Fig. 8 shows the normal stress-strain curve OCD of a specimen. According to equation (3) the external stress σ at any point of the curve exceeds the internal stress σ_i at this point by a small constant

amount determined by the rate of strain. As σ increases, so σ_i increases by work hardening. Suppose that at the point C where σ_i has the value σ_{ic} the stress is held constant. The specimen continues to creep, because σ exceeds σ_i. As creep continues, work hardening continues, and σ_i increases. After a small creep strain s the internal stress is given approximately by

$$\sigma_i = \sigma_{ic} + \gamma s. \qquad (6)$$

The value of γ will probably not be very different from the slope of the tangent CD to the normal stress-strain curve. The rate of strain is then given by a formula of the type

$$ds/dt = A \exp\left[-B(\sigma_{ic} + \gamma s - \sigma)^{\frac{3}{2}}/kT\right]. \qquad (7)$$

This gives a dependence of s on t which is roughly of the form observed, but if the theoretical curve is fitted to the observations for moderately large values of t, the theoretical rate of creep in the early stages is very much less than that observed. Orowan suggested that each dislocation, when it moves, releases an avalanche, and that these avalanches are larger in the early stages of creep than in the later. This is probably true, but it has not been possible to incorporate this idea into the theory without making arbitrary assumptions. Mott[1] and Smith[9] have developed a theory of transient creep on an entirely different basis. A genuine hardening during creep would be represented by an increase in the height of the potential hills in Fig. 3. They neglect this effect, but point out that in the early stages of creep there are many dislocations which have only small potential barriers U to overcome. These soon move, giving a rapid initial rate of creep, and leaving the specimen in a state where the most easily moved dislocations have larger barriers to cross. These move much more slowly, giving a slower creep rate, and leaving only dislocations which have to cross still larger potential barriers. This idea of the exhaustion of easily-moved dislocations leads to a creep which depends on time according to a law of the form

$$S = A(\log \nu t)^n, \qquad (8)$$

where ν is the frequency of oscillation of a loop of a dislocation in its potential trough, and is estimated as 10^8 sec.$^{-1}$, while n may be 1 or $\frac{3}{5}$. The theory represents creep under low stresses rather well, but cannot account for cases in which the strain in transient creep exceeds the deformation occurring in the first second after the load is applied.

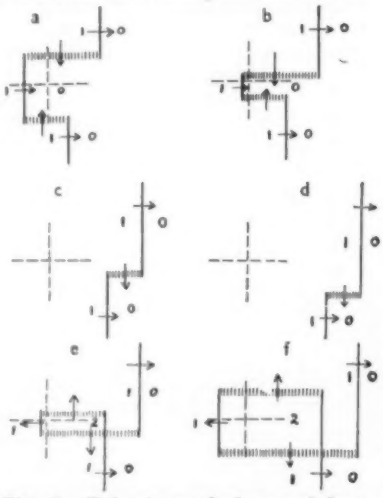


Fig 9.—Behaviour of slow and fast dislocations. Continuous lines are segments of edge type, broken lines are segments of screw type. Each segment moves in the direction of the arrow. Figures 0, 1, 2 are numbers of atomic spacings through which slip has occurred in each region of the slip plane. The two screw segments of (a) approach in (b). If they are moving slowly, they annihilate, as in (c), and the total length of dislocation moving from (c) to (d) is less than that in (a). If they move fast, they cross, as in (d), and the total length of dislocation moving from (d) to (e) is greater than that in (a).

The Multiplication of Dislocations

When a crystal creeps under constant load, the motion is often not continuous, and the extension takes place in a series of jerks. This suggests that when a dislocation begins to move it may give rise to a large number of dislocations moving in the same or neighbouring glide planes. A dislocation moving slowly cannot do this: when the dislocation of Fig. 1 reaches the point T′ the motion ceases. Similarly, if two slowly moving dislocations of opposite sign meet, they annihilate. Fig. 9(a) represents a dislocation which is partly of edge and partly of screw type. All segments of this dislocation are moving as indicated by the arrows in directions which increase the area which has slipped through one atomic spacing and decrease the area which has not slipped. The next configuration of this dislocation is shown in Fig. 9(b). If the motion is slow, the two screw elements which are about to meet will annihilate, leading to the configuration of Fig. 9(c), where the total length of dislocation moving is less than in Fig. 9(a). Frank[1] has pointed out that fast-moving dislocations may be expected to behave differently. A dislocation travelling with a speed approaching that of sound has a kinetic energy greater than the potential energy of a dislocation at rest. When the dislocation of Fig. 1(a) reaches T′, its potential energy is roughly equal to the energy required to expose a new row of surface atoms at T′,

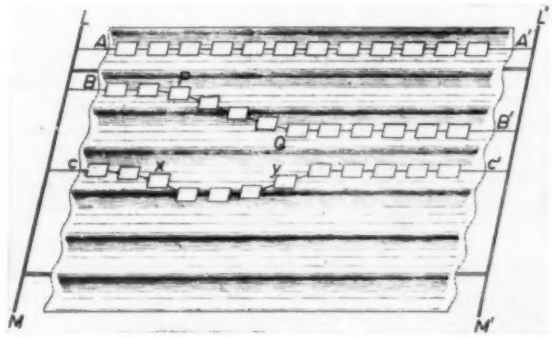


Fig. 10.—Mechanical model of a crystal. The rollers on a taut wire represent a row of atoms. The plane of atoms below is represented by a sheet of corrugated iron, the binding force by the weight of the rollers. AA′ are atoms in a perfect lattice. The row BB′ has a screw dislocation at PQ; the row CC′ has two screw dislocations of opposite sign. A shearing stress is simulated by raising the edge LL′.

both being of the order of μa^2. If it is moving fast, its kinetic energy is available to form a new reflected dislocation travelling back along T′T. The wave of compression above TT′ reflects as a wave of rarefaction, and the new dislocation is an edge dislocation of opposite sign. Its motion along T′T causes slip to continue in the same direction as before. Under the influence of the force (1), this new dislocation accelerates to a speed comparable with that of sound, and again reflects at T with change of sign. An unlimited amount of slip can thus occur on the same glide plane if a single dislocation starts to move. Similarly the irregularity of the dislocation in Fig. 9(a) may lead to the generation of a new dislocation loop, for if the two screw elements approach one another fast

enough they will pass through each other before there has been time for their energy to be dissipated in sound waves. This leads to the configuration of Fig. 9(e). The newly formed loop enclosing a region which has slipped by two atomic spacings continues to grow as in Fig. 9(f).

Frank and v. d. Merwe made a model (Fig. 10) to illustrate these effects. A number of rollers are threaded on a taut wire, the ends of which run freely on guide rails LM, L′M′. These rollers represent a row of atoms. The periodic field of the plane of atoms on which they lie is represented by a sheet of corrugated iron. If the rollers all lie in one trough of the corrugated iron, as in AA′, the crystal is perfect. By raising the ends L, L′ of the guide rails and the corresponding end of the corrugated iron, we simulate a shear stress tending to make the row of atoms AA′, and the rows which may be imagined to lie in the other troughs, slip over the corrugated iron from LL′ towards MM′. As we increase the tilt, there is an increasing elastic displacement, each roller moving in its own trough, but the perfect crystal is strong, and the rollers do not move out of their troughs until a large shear stress is applied.

The row BB′ represents a crystal containing a single screw dislocation. Between P and Q the line of rollers crosses from one trough to the next. If we imagine a similar array in every trough, so that a line of faulting runs through P and Q parallel to LM right through the crystal, we have a screw dislocation. If the end LL′ is lifted only slightly, the dislocation moves to the left, the atoms to the left of Q falling into the trough immediately below them, while the atoms to the left of P are pulled up into positions on the crests of corrugations. When the line of dislocation moves across the crystal from the right edge near L′ M′ to the left edge near LM, the plane of atoms represented by the line of rollers, and by the other lines of rollers which we imagine to lie parallel to them, slips one wavelength in the direction LM over the corrugated iron. If the tilt of the model is only slight, the dislocation comes to rest when it reaches the edge of the sheet, dissipating its energy in vibrations. If the model is tilted through a larger angle, the dislocation moves faster, the atom B overshoots the next trough and comes to rest in the next trough but one. A screw dislocation of the opposite sign is formed and travels across the model from left to right. By repeated reflections, the line of rollers BB′ works its way down the model until it finally reaches the end MM′.

The row CC′ represents a more complicated case, analogous to that of Fig. 9. Here we have two dislocations of opposite sign at X and Y. When the model is level, these two attract one another, showing the attraction of dislocations of opposite sign pointed out by Taylor in his original paper. If X and Y are close enough, this attraction overcomes the friction, and the two run together and annihilate. If we tilt the model, X and Y move apart, and, with a large enough tilt, they each reflect at the edge, forming dislocation of opposite sign. Owing to the large tilt, these new dislocations move fast, and when they run together they do not annihilate, but pass through each other, to reproduce the arrangement CXYC′, but with each roller two wavelengths further down the model.

Solid Solutions and Precipitation Hardening

In the sections on movement of dislocations and transient creep we considered systems in which the average wavelength Λ of the internal stresses was much larger than the radius of curvature ρ (eq. (5)) into which the internal stresses could bend a dislocation. A dislocation can bend into a curve of radius comparable with the atomic diameter a only under stresses comparable with the elastic modulus μ. In a solid solution the approximation $\Lambda \gg \mu a/\sigma_i$ no longer holds and we shall now consider the other limiting case of $\Lambda \ll \mu a/\sigma_i$. The dislocation runs almost straight through regions much longer than Λ, as in Fig. 7(b). Over a straight length L of the dislocation, the force acting on the dislocation changes sign $N=L/\Lambda$ times. There are L/Λ elements each subject to a force $\sigma_i a\Lambda$, and of varying sign. By ordinary statistical theory, the resultant of all these forces is likely to be $N^{\frac{1}{2}}$ times the force on each element, or $\sigma_i a\,(L\,\Lambda)^{\frac{1}{2}}$. An external stress σ acting on this length of dislocation exerts a force $\sigma a L$. If L is sufficiently large $\sigma a L$ will always be greater than $\sigma_i a(L\Lambda)^{\frac{1}{2}}$, so that a long dislocation which remains perfectly straight will move under even a very small external stress. In fact, although the dislocation behaves as almost perfectly straight over distances as small as Λ a sufficiently long segment of the dislocation may be regarded as flexible. We consider that the shortest segment L_c which is effectively flexible under the external stresses is one in which the mean directions of its ends are inclined at an angle of a radian. According

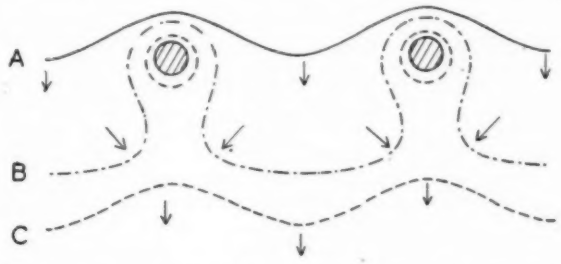


Fig. 11.—Passage of a dislocation between widely spaced obstacles (after Orowan). The dislocation A is held up by obstacles a distance Λ apart, and bulges (B) into a curve with radius of curvature at least $\frac{1}{2}\Lambda$. Under a sufficient stress the bulges join, to form a dislocation beyond the obstacles, together with a closed loop of dislocation round each obstacle (C).

to equation (5), each short segment of length Λ has a radius of curvature $\mu a/\sigma_i$, so its ends are inclined at an angle $\Lambda\sigma_i/\mu a$. The resultant deviation after L_c/Λ segments is $(L_c/\Lambda)^{\frac{1}{2}}\cdot\Lambda\sigma_i/\mu a$. The critical value of L_c is obtained by setting this angle equal to 1, which gives

$$L_c=\mu^2a^2/\Lambda\sigma_i^2. \qquad (9)$$

The number of segments in this critical length is $N_c=L_c/\Lambda=(\mu a/\Lambda\sigma_i)^2$, which by hypothesis is large. The mean stress $\bar{\sigma}$ over this length is $N_c^{-\frac{1}{2}}\sigma_i$ which gives

$$\bar{\sigma}=\Lambda\sigma_i^2/\mu a, \qquad (10)$$

and the yield strength of the crystal is approximately equal to $\bar{\sigma}$. In (10), Λ depends only on the concentration of dissolved atoms, σ_i depends on the concentration, and is proportional to the change in lattice parameter when 1 atomic per cent. of solute is dissolved in the matrix. It follows that solution hardening is proportional to the square of the strain around each solute atom, in agreement with experiment. The dependence on concentration given by (10) is almost linear.

Suppose now that precipitation begins, and for simplicity assume that the particles of precipitate are

spherical. Then σ_1 in (10) remains unaltered, for the stress distribution is simply a model of that in the solid solution, on a larger scale. The strength therefore increases in proportion to Λ, the mean distance between precipitates, and this increase continues as long as the approximation $\Lambda \ll \mu a/\sigma_1$ remains valid. This is precipitation hardening. The hardness for critical dispersion has not been calculated. For coarser dispersion, Orowan[10] has shown that the yield strength diminishes, becoming inversely proportional to Λ when Λ is very large. Consider the dislocation A in Fig. 11, which is held up by two obstacles a distance Λ apart. On the soap film analogy, the dislocation bulges forward between the obstacles, as at B. The smallest radius of curvature which the dislocation can have in this bulge is $\frac{1}{2}\Lambda$, when the bulge is semicircular. The force on unit length is then $2T/\Lambda = 2\mu a^2/\Lambda$, and the external stress which will produce this force is

$$\sigma = 2\mu a/\Lambda. \qquad (11)$$

For any stress larger than this the dislocation bulges until it is semicircular, and the bulge continues to grow with a radius of curvature which is now increasing. The "bubble" bursts. A closed ring dislocation forms round each obstacle, and the bulges join to form a continuous dislocation C travelling freely beyond the obstacles.

The Bubble Model

It is not easy to construct a realistic model of a metal crystal. The "atoms" must have a long-range attraction and a short-range repulsion, and the repulsion must not vary too violently with distance, as occurs if the "atoms" are made of steel or wood. There must be no forces of static friction producing non-central forces between atoms in contact. To make large regular crystals, the model atoms must be very uniform in size, and, since very large numbers are required to study such phenomena as recrystallisation, they must be very cheap to produce. Bragg[11, 12] has shown that all of these requirements are satisfied by a raft of bubbles floating on the surface of a soap solution. The bubbles form regular two-dimensional crystals, with well-marked grain boundaries. Various lattice defects, such as interstitial atoms and vacant lattice sites, are observed, and edge dislocations are also formed. When the raft is slowly deformed, the dislocations move across their glide planes in the way considered in the present theory. New dislocations are formed at grain boundaries, or in pairs of opposite sign in the interior of grains. The law of force depends on the size of the bubbles, and Bragg and Lomer[13, 14] have shown that a close approximation to the law of force between real atoms of metals is obtained with a bubble diameter of about 1·2 mm. Corresponding to the change in the law of force, the length of a dislocation varies with the size of the bubbles, increasing from a few bubbles in length for large bubbles to as much as fifty for small bubbles. Bragg and Lomer have measured the critical strain at which dislocations are formed, and the reduction of this strain by imperfections such as notches in the edge of the raft which concentrate the stress. A dislocation already formed runs along its slip line under very small stresses.

Bragg[1] has also considered the theoretical yield strength of a fine-grained material. Suppose the number of atoms in the edge of a grain is N. When a dislocation travels across its glide plane, the plastic strain produced is the displacement by one atomic distance of two planes N atoms apart. The shear strain is thus an angle of $1/N$. Let the shear stress applied to the specimen be σ, leading to an elastic shear strain of σ/μ. In any individual grain this strain σ/μ is imposed by its neighbours. If this grain alone slips, by the minimum possible strain of $1/N$, the elastic strain in this grain changes from σ/μ to $(\sigma/\mu)-(1/N)$. The strain energy in this grain decreases only if σ/μ is greater than $1/2N$, which leads to

$$\sigma > \tfrac{1}{2}\mu/N. \qquad (12)$$

In fact the factor $\frac{1}{2}$ in (12) is a lower limit, and the yield strength may be of the order of $5\mu/N$. This is of the right order of magnitude for heavily cold-worked metals, where estimates of N are available from X-ray data.

Interaction of Dislocations and Dissolved Atoms

In the dislocation of Fig. 1(a), the lattice above the glide plane is compressed, and the lattice below is expanded. Cottrell[1] has pointed out that if the metal contains, in substitutional solution, atoms of different radius from the solvent atoms, these will cluster preferentially near the dislocation, the large atoms in the expanded region of the lattice and the small atoms in the compressed region. If the dilatation of the lattice at some point is θ, and the difference between the atomic

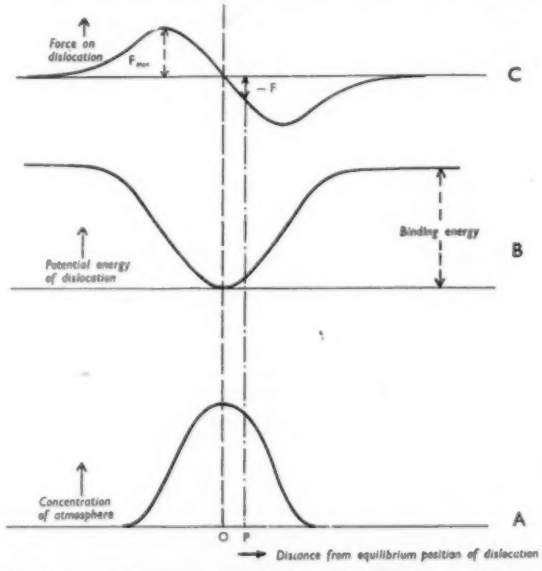


Fig. 12.—(a) Concentration of atmosphere of dissolved atoms as a function of distance from a dislocation. (b) Potential energy of the dislocation if it moves from the centre of its atmosphere. (c) Force on the dislocation at the same point.

volumes of solvent and solute is δv, the energy U binding a solvent atom to this point is given by

$$U = K\theta\delta v, \qquad (13)$$

where K is the bulk modulus of the material. When equilibrium is attained, the concentration c of solute atoms near this point exceeds the concentration c_0 in the bulk of the metal in the ratio.

$$c/c_0 = \exp\,(U/kT), \qquad (14)$$

provided that $(c-c_0)\delta v$ is small compared with θ.

Consider now a dilute solid solution which is strained to introduce dislocations. If it is tested immediately afterwards, the dissolved atoms are still distributed at random, and the dislocations are free to move. If the specimen

is annealed for a sufficient time, some of the solute atoms migrate to the dislocations, so that each dislocation is surrounded by a " Debye-Hückel " atmosphere of solute atoms. Under the influence of stress, the dislocation can only move a short distance comparable with the dimensions of the atmosphere before it is pulled back by the attraction of the atmosphere. This attraction is zero for the dislocation in the centre of its atmosphere, rises to a maximum, and then falls to zero again as the dislocation breaks free (Fig. 12).

Under a small applied stress F, the dislocation moves from its equilibrium position O to a new position P. The atmosphere is attracted towards the new position of the dislocation, and for small stresses the force on each atom is proportional to F. The mobility is D/kT, where D is the coefficient of diffusion of the solute atoms, and the drift velocity is proportional to DF/kT. This movement of the solute atoms reduces the retarding force on the dislocation, which finds a new position of temporary equilibrium. Finally, under small stresses, a steady state is set up in which the dislocation drifts in the direction of the applied force, to a rate proportional to DF/kT, dragging its atmosphere behind it. This is the behaviour observed in microcreep[15], and Cottrell has shown that, on the reasonable assumption that the density of dislocations in a soft single crystal is $10^8 cm^{-2}$, the rate of creep calculated is comparable with that observed.

If a force larger than F_{max} in Fig. 12 is applied, the dislocation tears free from its atmosphere, and normal flow occurs. The stress may now be reduced and the specimen continues to flow normally, because the dislocations are no longer surrounded by atmospheres. This effect occurs in microcreep, and the theory was also used by Cottrell and Gibbons[16] to explain the " thermal hardening " of cadmium crystals[17]. There is a narrow intermediate range of stresses under which the dislocation cannot escape from its initial complete atmosphere, but can escape from the less tightly bound atmosphere which forms as it moves. It is under these stresses that yielding occurs some time after the load is applied.

The most important application of these ideas is in the theory of the mechanical effects of carbon in iron[18]. Nabarro[1] showed that strain ageing could be explained by the diffusion of carbon towards dislocations, and that the activation energy was the same as that for the diffusion of carbon. The effects of carbon, which is in interstitial solution, differ for two reasons from those of atoms in substitutional solution. In the first place, carbon not only expands the lattice, but also distorts it from cubic to tetragonal. Therefore large strains can be produced even though the carbon atoms do not migrate considerable distances to build up regions of high concentration, but only move to adjacent interstitial positions, producing a tetragonal deformation. These shear strains can lock a screw dislocation as easily as an edge dislocation, whereas the interaction between a substitutional solute atom and a screw dislocation must be weak. Secondly, the volume change δv produced by the presence of a carbon atom is very large, and the energy U in (13) is much greater than kT, if the atom is inserted close to the axis of a dislocation. The atmosphere does not have a concentration proportional to the concentration in the bulk of the metal, as in (14), but is saturated even in very dilute solutions. In fact, a single carbon atom in each atomic plane just below the axis of a dislocation is probably sufficient to relieve the dilatational stress completely, and the " atmosphere " reduces to a single line of carbon atoms. The contribution of this regular line of carbon atoms to the electrical resistance should be much smaller than the contribution of the same number of atoms arranged at random in the lattice, and in this way Churchman [19] has explained the fall in resistance during strain ageing in a roughly quantitative manner.

Since the atmosphere is so concentrated, the curves in Fig. 12 are all very narrow. The binding energy of the dislocation is, as in other cases, comparable with its own self-energy of μa^2 per unit length, and the potential energy curve (Fig. 12(b)) becomes very steep. The force F_{max} required to pull the dislocation away is therefore very large, which accounts for the large upper yield strength of iron. Because the binding force is of very short range, a small bulge in the dislocation, consisting in the displacement of an element only a few atoms long through a distance of a few atoms, will continue to grow under external stress, allowing the whole dislocation to break away. Though the energy per unit length of this bulge is large, it is so short that the activation energy required to form a bulge which will grow remains comparable with kT, and the yield strength shows a temperature dependence several times as great as that observed in other materials. Cottrell and Bilby have developed this idea to obtain rather good agreement with experiment.

REFERENCES

1 1947 Bristol Conference on Strength of Solids, The Physical Society, London (1948).
2 Recent Advances in the Physics of Metals, Butterworths, London, in the press.
3 Kochendörfer, A., Plastische Eigenschaften von Kristalle, Springer, Berlin (1941).
4 Laurent, P., *Rev. Met.*, **42** (1945), 79, 125, 156, 194, 230.
5 Masing, G., *Z. Physik*, **124** (1948), 586.
6 Burgers, J. M., *Proc. Kon. Ned. Akad. Wet.*, **42** (1939), 293.
7 Frank, F. C., to be published.
8 Orowan, E., *J. West Scotland Iron Steel Inst.*, 17th Feb., 1947.
9 Smith, C. L., *Proc. Phys. Soc.*, **61** (1948), 201.
10 Orowan, E., Symposium on Internal Stresses, The Institute of Metals, London (1948), 451.
11 Bragg, W. L., *J. Sci. Instruments*, **19** (1942), 148.
12 Bragg, W. L., and Nye, J. F., *Proc. Roy. Soc. A*, **190** (1947), 474.
13 Bragg, W. L., and Lomer, W. M., *Proc. Roy. Soc. A*, **196** (1949), 171.
14 Lomer, W. M., *Proc. Roy. Soc. A*, **196** (1949), 182.
15 Chalmers, B., *Proc. Roy. Soc. A.*, **156**, (1936), 427.
16 Cottrell, A. H., and Gibbons, D. F., *Nature*, **162** (1948), 488.
17 Smith, C. L., *Nature*, **160** (1947), 466.
18 Cottrell, A. H., and Bilby, B. A., *Proc. Phys. Soc., A*, **64** (1949) 49.
19 Cottrell, A. H., and Churchman, A. T., *J. Iron Steel Inst.*, July, 1949.

Smethwick Drop Forgings, Ltd.

Long Service Awards

A DINNER and Entertainment was given on Friday, July 15th by the Directors of Smethwick Drop Forgings, Ltd., in recognition of long service of employees, both active and retired. Some 200 employees and wives sat down to dinner at the Botanical Gardens, Edgbaston. The function was presided over by Mr. Ralph Bennett, Chairman and Managing-Director, supported by his co-Directors and their wives.

On looking through the list of employees present, Mr. Bennett said he was struck by the prevalence of family names and he felt that it was perhaps the greatest recommendation any firm could have. Many of those trusted members of the firm had served for nearly a lifetime and their sons were following an example of loyalty and earnestness which might be the envy of any industrial concern. Mr. Bennett concluded his remarks with a further tribute to the devotion of the older employees and announced that all those who had been with the company for 25 years or more would be presented with a suitably inscribed watch.

Fourth Empire Mining and Metallurgical Congress

Mineral Resources and their Utilisation

The depletion of many sources and the danger of serious restriction of industry unless new deposits of minerals are found and the most made of existing sources by skilful mining and new developments in alloying and subsequent fabrication and finishing were discussed at this Congress which brought together experts from 82 countries. Technical sessions were held at Oxford, after which the delegates toured shipyards, mines and works in various parts of Britain. Only a brief summary is given here of part of the technical sessions.

CONVENED by the Empire Council of Mining and Metallurgical Institutions, this Congress, held in London and the provinces from July 9th to 23rd, was the fourth to be held. The initial Congress was held at the Empire Exhibition at Wembley in 1924 at which it was decided to hold a similar Congress every third year. This was carried out in 1927 and 1930 when the second and third meetings were held in Canada and South Africa respectively. The fourth meeting was arranged to be held in Australia in 1933, but, due to unsettled conditions, it was abandoned and further difficulties arose which caused postponement until it was found possible to make arrangements to hold the Congress in Britain this year.

The main purpose of the Congress was to provide a meeting ground for those engaged in developing the mineral resources of the Commonwealth and in the efficient utilisation of the products of the mines; and, since minerals hold a dominant place in modern life, it is important that mining and metallurgical experts should meet and discuss problems associated with minerals that have a national and international significance. Whether mankind will continue to need more and more kinds of minerals in ever increasing quantities concerns not only mineral industries, but has wide political importance. Many believe firmly in increased consumption of goods, but it does not follow that the demand for minerals will keep on growing for ever, even if we ignore the exhaustion of mineral deposits. There have been many economic changes since James Watt first contrived to harness steam. In terms of minerals, the need for coal to burn under boilers came first, next the demand for metals to make machines, and later the demand for more diverse materials, for ever more complex products and services. The outputs of science are spread so wide that it is difficult now to determine which frontiers are being pushed ahead fastest.

The importance of minerals was emphasised at this Congress and members not only visited research laboratories, mines and works in a number of districts, but held several technical sessions at Oxford where the range of subjects included a lecture by Sir John D. Cockcroft on metallurgical and mining aspects of atomic energy; nine papers concerned with mineral resources; four papers dealing with modern methods of prospecting; a lecture by Dr. W. Hume-Rothery on the general theory of metal and alloys; six papers on physiological and psychological effects of heat, and humidity on workers in deep mines and metallurgical works; two papers dealing with drilling for and production of petroleum, including a lecture by Professor V. C. Illing; twelve papers dealing with metallurgy and metallurgical industries; four papers on present-day trends in mineral dressing; and a lecture by Dr. Charles Camsell, C.M.B., L.L.D., F.R.C.S., on miners as pioneers.

Presidential Address

The Congress was held under the presidency of Sir Henry Tizard, G.C.B., A.F.C., F.R.S., chairman of the Advisory Council on Scientific Policy. In his address he said the whole of our material civilisation depends on drawing on the capital resources of the earth. We discover the places where nature has concentrated minerals in a way that we do not understand; we extract them, we concentrate and refine them still further, and then dissipate them completely in use. That process obviously cannot go on for ever. How long will it go on? That question is rapidly becoming one of practical importance. In his lifetime more irreplaceable minerals have been dissipated than in the whole previous history of the world. The rate of consumption goes on increasing, and no one is going to put a limit to the rate. No one can be certain, from existing knowledge, that some of the metals on which so much depends, such as lead and tin, will be available in sufficient quantity in a hundred years' time. Some metals exist in enormous accessible quantities, for instance magnesium, which if necessary could be obtained in unlimited quantities from sea water. But we must even cast doubts upon the future supply of iron ore. The rich Lake Superior deposits are being rapidly dissipated. Broadly speaking it is true to say that the rate of discovery of minerals of economic importance has been falling fairly steadily for 20 or 30 years. What we do not know is whether this decrease is due to the fact that the minerals are not there or due to the fact that our methods of finding them are out of date.

As an encouragement to optimists Sir Henry examined this problem in another way. Although the rate of consumption of minerals is great, the actual volume that has been consumed is very small compared to the size of the earth. A rough calculation shows that the total volume of liquid fuel extracted from the earth so far comes to between 1 and 2 cubic miles. The total volume of iron ore, estimated at Fe_2O_3, extracted from the earth so far is about $\frac{1}{2}$ cubic mile, and if one put all the other metalliferous minerals together, one would now find that the total volume amounted to another $\frac{1}{2}$ cubic mile. Coal, of course, is different; well it is, but not so different as one might imagine. The total volume of coal extracted from the earth since the beginning of time

is between 10 and 20 cubic miles. When the whole size of the earth, which is accessible to us is considered, we might justly say that we are only scratching at its surface. On the average we do not extract minerals from depths exceeding 1 mile. The total area of the land surface of the earth is about 60,000,000 square miles. So the total volume of the land to the depth of 1 mile is 60,000,000 cubic miles, out of which we have so far taken, less than 20 cubic miles of coal, rather over 1 cubic mile of petroleum and say roughly 1 cubic mile of metalliferous minerals extracted for their metals. It would certainly be very odd if in that large volume there are not still very many cubic miles of useful and exploitable material. In the case of coal there will be sufficient to last at least another thousand years, and after all a lot may happen in a thousand years. We may get atomic energy as a source of fuel, heat and power and possibly find a method of synthesizing the rarer metals in short supply from other elements. A great deal can happen, but meanwhile we must face the possibility of a shortage of certain essential minerals within the life-time of some people now living.

The last stage in providing metals to meet the ever more stringent requirements of engineers rests with the metallurgists. The science of metallurgy has made great strides in recent years. Mathematical and experimental physicists for many years have been absorbed in the problems of the atom and as a result of their work clearer scientific principles have been developed which can guide the practical metallurgist in his work. It is still true to say, however, that it is not yet possible to predict, with any degree of certainty, what combinations of metals are likely to be needed for certain purposes.

Technical Sessions

Several matters on which the President touched in his address were presented in greater detail in subsequent lectures and in papers at the technical sessions, from the latter of which fruitful and interesting discussions arose, but, owing to limited space at our disposal, it is possible only to give brief summaries of some of the papers on the metallurgical industries.

THE ZINC SMELTING INDUSTRY IN GREAT BRITAIN

By S. W. K. Morgan

During the 1914–1918 war zinc ore was smelted at several works in Great Britain. In 1918 nine were operating producing a little over a third of the home consumption of zinc. During that war the Government supported a project to build a modern distillation plant at Avonmouth, but it was not completed when the war ended. For some years immediately following that war the industry was in a low state and, when the Government subsidy was withdrawn, it collapsed and the only works operating in 1930 were those owned by the National Smelting Co., Ltd. at Avonmouth and Swansea and the Seaton Carew works operated by that time by the Sulphide Corporation.

In 1924, the Swansea Vale Spelter Co., practically the only representative of the industry left in South Wales, was taken over by the National Smelting Co., Ltd. which later became the Imperial Smelting Corporation, Ltd. At the same time the Company acquired the partly completed Government sponsored plant at Avonmouth which they completed and put into operation in 1929. Although the retort plants at Seaton Carew and at Birmingham were operating during the 1939–1945 war they are now shut down and all the zinc produced in this country is smelted at the Avonmouth or the Swansea Vale works.

No zinc ore in commercial quantities is now mined in this country and the smelters at Avonmouth and Swansea rely entirely on imported concentrates, approximately 170,000 tons per year being treated from which is extracted 70,000 tons of zinc (14,000 tons being in the form of high purity metal.) The sulphur dioxide evolved in the roasting operation is converted into 160,000 tons per year of sulphuric acid (expressed as 100% H_2SO_4), which provides approximately 10% of the total national consumption of this acid. Some 150 tons per year of cadmium are recovered together with smaller quantities of metals such as arsenic and thallium.

The author describes and outlines the development and present-day operation of these two zinc smelting plants at Avonmouth and Swansea, and emphasises that their survival is due to a readiness to adopt the most economical methods of production, coupled with attempts to make full use of every value in the incoming ore. He realises that difficulties will not diminish in the future. No English ores are available and consequently all of the 170,000 tons of concentrates required annually must be imported, and bought in competition with smelters abroad. The future must depend to a considerable degree upon our ability to improve our existing processes and to adopt new methods if these are proved commercially superior under our conditions.

THE NICKEL INDUSTRY: TWENTY YEARS ON

By Sir William Griffiths, D.Sc.

World consumption of nickel had nearly reached 10,000 short tons in 1900, but by 1912 the 30,000-ton mark had been passed and during the 1914–1918 war consumption rose to nearly 50,000 tons. When that war ended yearly world consumption dropped to below the 10,000 ton level. As a result of extensive research and development new peace-time uses for nickel were developed and by 1927 world consumption had risen to 40,000 tons per annum and by 1929 68,000 tons.

The new peace-time uses which had been found for nickel alloys during the nineteen-twenties were for the most part associated with the growing requirements, particularly in the engineering industries, for materials with improved or special properties. The automobile, and especially the heavy commercial vehicle, industry provided an important market for the nickel-alloy steels, as also did power-generating equipment, railway rolling stock, and industrial machinery of all kinds. The chemical, food, marine, and domestic-appliance industries took large quantities of corrosion- and heat-resisting alloys—such as the "austenitic" steels, "Monel," and other nickel-copper alloys, malleable nickel itself, and the nickel-chromium alloys. The markets for nickel depended to a great extent on the growing demand for such features of the modern world as rapid and safe transport, increased industrial mechanisation, availability of a wide variety of foods (refrigerated or canned), electric lighting and heating, radio in the home, domestic labour-saving equipment, and so on.

It was thus inevitable that the crisis period of the early nineteen-thirties, with its restriction of credit and

lowered standard of living for much of the population of many countries, should have had a serious effect on the consumption of nickel. By 1932 the consumption figure had fallen to just above 20,000 short tons and the output of mines, smelters, and refiners everywhere had to be drastically curtailed.

The principal producer, however, in no way cut down its expenditure or effort on research and development; rather was the search for new alloys and new applications increased. Thus it was that as soon as business conditions took a turn for the better, the demand for nickel promptly returned and again rapidly increased. By 1937 world consumption had reached a figure exceeding 100,000 tons, while the peak war consumption of the U.S.A., U.K. and the British Commonwealth exceeded 140,000 tons per annum. Although the end of the war in 1945 resulted in a cessation of many uses for nickel, consumption in the U.S.A. and U.K. soon exceeded any pre-war annual consumption. The over-all position now is that, despite the small requirements of some countries which, before the war, were considerable consumers, the world demand for nickel is already at a peace-time record. In 1948 the world outside the U.S.S.R. used over 130,000 tons of nickel, while Russia must have consumed many thousand tons of domestically produced metal.

FUTURE TRENDS IN THE BRITISH IRON AND STEEL INDUSTRY

By Sir Charles Goodeve, F.R.S.

The shortage of capital equipment since the end of the war has brought home to the public more clearly than ever before the key position of steel in the world economy, and the importance of using steel to the best advantage. There is still need, however, for more publicity about the types of steel available and for the large steel using industries and their trade and technical associations to give a lead by ordering the most efficient steel for each of their various requirements.

Sir Charles emphasised that the greater bulk of steel has, for some time, been made in "integrated" steel works, the optimum degree of integration being determined by the savings in fuel, transport, and in overhead charges as set against the loss of flexibility of operation and layout. He referred to the saving resulting from siting coke ovens near blast furnaces, not only in cost of transport, but in reduced breakage of the coke during transport and the use of coke breeze as boiler fuel and in sintering.

The planned increase in steel production from a rate of 14·88 million tons, attained during 1948, to about 17·5 million tons in 1953–54 involves increased raw materials. In 1948 the proportions of scrap to iron used in steel manufactured were in the ratio 56–44, but it is improbable that supplies of imported or home scrap can be increased, the proposed increase in production, therefore, must come substantially from new iron which will involve increased ore consumption. Home ore fields are approaching the limit of depth for open-cast working, and it will soon be necessary to undertake underground mining to keep up the supply of ore. This is particularly true of the Frodingham ores and efficient underground techniques should be prepared now. The richer ores in British ore fields are steadily being used up and, at the same time, higher production per furnace has been required, with the result that more and more attention has been given to ore preparation.

The position of the blast furnace, holding, as it does in Britain, a monopoly in the production of iron from ore, is unlikely to be challenged for many years, but the continuous pressure for increased outputs, improved qualities, lower costs, etc., on the one hand, and the struggle against falling coke and ore qualities on the other, provides the stimulus for extensive research and development. Our knowledge of the physics and chemistry of the processes going on in the blast furnace is increasing rapidly at the present time and one can look forward to important changes in design and practice in the near future.

Sir Charles said the trend in all steelmaking processes is towards improved instrumentation and, the subsequent step, automatic control. Already a considerable number of furnaces have gone a long way along various lines towards automatic control, with substantial improvements in output and quality of product.

He discussed the size and design of open-hearth furnaces, the Bessemer process, electric furnaces, and the physical chemistry of the steelmaking process. On the production of steel castings he referred to oxygen enrichment of the air blast, precision casting, and centrifugal casting. Continuing, he had much to say on developments in alloy steels; he emphasised that the shortage of steel resulting from the war has increased the importance of using the right steel for the right purpose. This has increased the demand for alloying elements by means of which steels can be made suitable for special purposes. Better steels at lower prices are needed, and, in order to obtain them, attention will have to be given to the methods by which the alloying elements are obtained.

SOME ASPECTS OF THE USE OF REFRACTORY MATERIALS

By F. H. Clews and A. T. Green

Refractory materials are indispensable to the conduct of almost all high-temperature metallurgical operations. From the aspect of heat transfer they may be utilised in three ways: to confine heat within a space, as in most furnaces; to transmit heat, as in various retort processes; and to store heat, as in furnace regenerators. No one material can perform all these functions well, although firebricks and silica bricks are regularly used in all three situations. This is explained by the fact that frequently thermal considerations are not the main factor; refractories are required to withstand the temperature, stress and chemical action to which they are exposed without undue deterioration. Superior and more enduring material for a particular purpose may have to be passed over on account of cost.

In this paper the authors consider trends in the refractories usage in some typical metallurgical operations, such as the basic open-hearth steel furnace; copper smelting and refining; coal carbonisation plant; and zinc retorts; and discuss possible future developments. In addition, the metallurgical applications of zircon refractories, mullite and high alumina refractories are considered. In conclusion, the authors state that when extracting metals from their ores the general tendency is for the richer ores to be utilised first and as they become exhausted means are devised for dealing with the materials of poorer quality. This often entails more severe conditions of temperature and corrosion for the refractories. The demand for increased output often reacts similarly. Added to this, increased labour

Continued on page 228

The Engineering and Marine Exhibition

A Record Display of Engineering Products

The number of exhibitors at the Engineering and Marine Exhibition, which opens at Olympia on the 25th of this month, will be greater than on any of the previous sixteen occasions on which this biennial exhibition has been held. It is an indication that the part which the engineering and shipbuilding industries can play in our economic struggle is fully appreciated. Welcome as is this increased interest, it magnifies considerably the difficulties in dealing adequately with the exhibits in the space available and as a result it has been necessary to confine our attention to those displays which are likely to be of particular interest to readers.

OCCUPYING for the first time the whole of the premises at Olympia, London, the 17th Engineering and Marine Exhibition, with which is incorporated the Welding Exhibition, will open on August 25th, and continue until September 10th. The Exhibition, which is organised with the patronage and active support of The British Engineers' Association, The Society of Motor Manufacturers and Traders, Ltd. (Marine Section), The British Electrical and Allied Manufacturers' Association, The Institute of Welding, and The British Acetylene Association, has been held every alternate year since 1906, except for interruptions caused by two world wars, and claims to be the largest exhibition in the world which is devoted solely to the display of engineering products. The last exhibition, in 1947, established a record in that 50% more space was available than in any previous exhibition of the series. That record was destined to be short-lived, for this year there is a further 25% increase in the space which will be shared by more than 500 exhibitors. All that is now needed to seal the success of the Exhibition is the placing of a record number of orders.

The accommodation available includes the ground floor and galleries of the Empire, National, and Grand Halls; and in the following notes on the exhibits, the stands are identified by the stand number, followed by the row letter (or name), and the name of the hall. Unless otherwise stated, the stand will be situated on the ground floor of the hall concerned.

EXHIBITS

It is impossible in the space available to give details of all the exhibits on show; we have concentrated, therefore, on those which we consider will be of interest to readers of this journal.

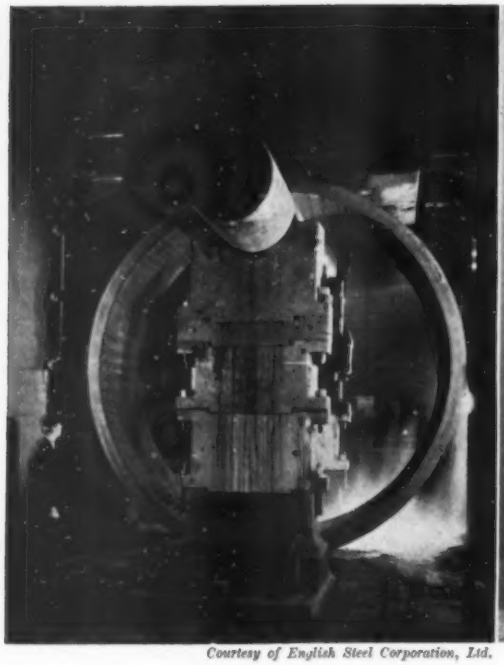
Steel

Although, both in marine and general engineering, steel is the main constructional material, it will be exhibited chiefly in the form of finished products, on the stands of the majority of exhibitors, rather than in its rough form as the product of the steelworks. The part played by the steelmaker in engineering achievements, will, however, be emphasised on a number of stands.

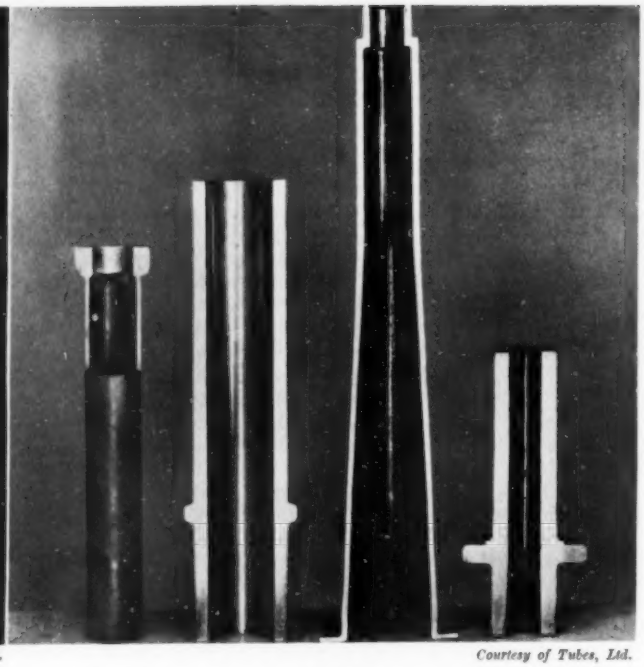
An exhibit which will undoubtedly catch the eye on the ENGLISH STEEL CORPORATION'S stand (14 H, Grand Hall) is the machined forged gear wheel rim, 11 ft. 9 in diameter, which towers over one end. 3 ft. 6 in. in

Courtesy of Cunard White Star, Ltd.

The Cunard White Star liner "Caronia" docking in New York harbour after her maiden voyage.



Courtesy of English Steel Corporation, Ltd.



Courtesy of Tubes, Ltd.

Forging a 14 ft. 3 in. diameter steel gear wheel rim. **Tubular steel forgings for aircraft and automobile components.**

width and 3⅛ in. thick, this rim weighs just over 7 tons, and a 120-ton ingot forged under a 7,000 ton electro-hydraulic forging press is required to make four such rims.

Examples of engineering products of E.S.C. also include a propeller shaft, 17 ft. 3 in. long, typical of ships' shafting supplied up to 80 ft. long, a forged marine rotor weighing 3¼ tons and a large diesel engine crankshaft 10 ft. long, weighing 1 ton.

To round off the stand is an attractive display of smaller marine engine crankshafts, and a large selection of Engineers' small tools and permanent magnets, made at the Manchester works of E.S.C.

The background of the FIRTH BROWN stand (7A H, Grand Hall) will contain a series of large coloured photographs suitably illuminated to show the various steel processes carried out in their works, whilst the tensile and other properties of Firth Brown Steels, graded from mild steel to the highest tensile steels, upwards of 100 tons per square inch, will be physically demonstrated by the difference in loadings.

Included in the exhibits will be Firth Brown "Speedicut" high speed steel and alloy steel bars; a hardened forged steel roll; marine and engineering steel castings; a gas turbine rotor; and steel weldments. A large die block and various rings for mobile crane rotating gear will also be seen.

Shown for the first time, the largest exhibit on the DARLINGTON FORGE stand (12 J, Grand Hall) will be a finished cast-steel back-up roll, 12 ft. 10 in. long, with body 3 ft. 10 in. diameter and weight 17 tons. The licence to manufacture this type of roll was obtained from U.S.A. and a mission visited the patentees in America last year to acquire technical data required for the successful production of the rolls.

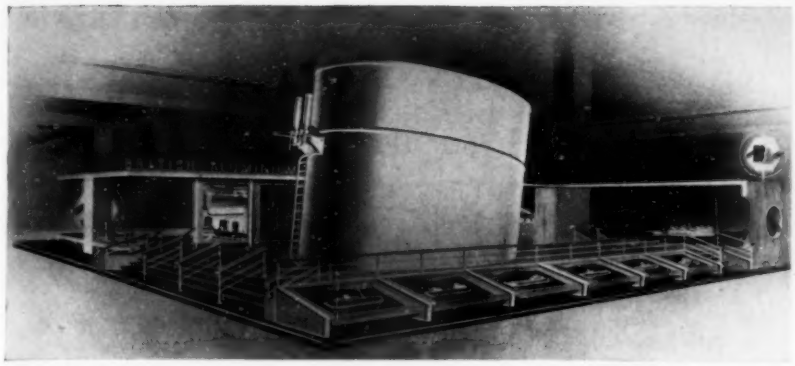
Other exhibits include a propeller shaft 18 ft. 8 in. long, weighing 9 tons, a forged rudder stock 4 tons, a diesel engine connecting rod 8 ft. long, 1¼ tons, and a diesel engine crank journal, 3½ tons, all exhibits being fully machined.

As many readers will know, the Forge is one of the leading producers of ships' structural castings and forgings, having been associated with such famous ships as the *Queen Mary*, *Mauretania*, *Nelson*, *King George V*, *Prince of Wales*, *Ark Royal* and more recently, the *Orcades*, *Himalaya*, *Edinburgh Castle*, *Rangitoto* and many others. The nature and assembly of the structural castings and forgings is shown by two scale models of those supplied for the *Queen Mary* and *King George V*.

THE UNITED STEEL COMPANIES LIMITED is the parent company for a number of well-known iron and steel producing firms. Prominent amongst these are the Appleby–Frodingham Steel Co., Steel, Peech and Tozer, Samuel Fox and Co. Ltd., Workington Iron and Steel Co., and United Strip and Bar Mills.

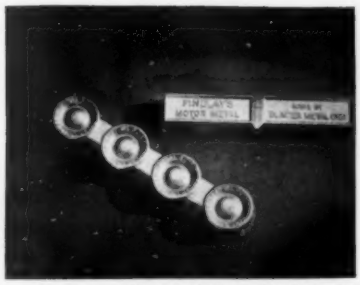
On THE UNITED STEEL COMPANIES' stand (9 V, Empire Hall), will be found exhibits representative of the various products for which these companies are famous, particular emphasis being given to their application in the engineering and marine industries. Boiler and ship plates; marine forgings; sheet piling; special and stainless steels; special iron and castings. In addition, samples of numerous steel sections used in ship construction will all be featured in an interesting and informative exhibit. Technical representatives will be in attendance at all times to answer questions and to give full information regarding the companies' products to all interested visitors.

TUBES LTD. (Stand 11 A, Grand Hall) are manufacturers of cold drawn seamless steel tubes and their



Courtesy of British Aluminium Co., Ltd.

An artist's impression of the British Aluminium Company's stand.



Courtesy of Glacier Metal Co., Ltd.

Tin- and lead-base white metal alloys.

exhibits will include boiler, superheater and steam tubes for a variety of applications, and precision tubes in mild steel, high carbon steel and alloy steel. The latter are made in sizes between $\frac{3}{4}$ in. and $8\frac{1}{2}$ in. O.D. and of many sectional shapes. The field in which tubing may be successfully and economically employed has been greatly enlarged by forging the tubes to approximately the shape and size of the finished part, thus saving material and reducing machining costs. Examples of such tubular forgings will be on show.

Also showing wrought steel products will be THE BROCKHOUSE ORGANISATION on Stand 13 B, Grand Hall. The products of the constituent firms will include drop forgings; ferrous and non-ferrous cold rolled sections; and hot rolled angles. Reference will be made to other products of the organisation in the sections on castings and tools.

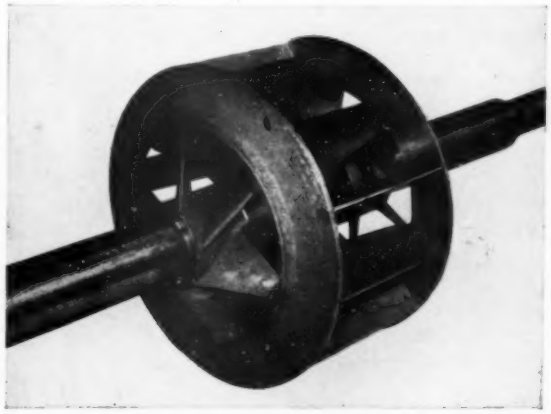
Non-Ferrous Metals

As a result of our war-time engineering activities, we have experienced a post-war shortage of steel. At the same time, we have been left with unusually large manufacturing capacity for certain of the non-ferrous metals, notably aluminium and, in consequence, we have heard a good deal in the last few years about the substitution of such materials for steel in many fields. At Olympia, the balance will be restored, to some extent, in that attention is drawn to the many applications where non-ferrous metals are used in their own right—because they are the most suitable materials for the purpose.

A case in point is the use of the Nimonic series of nickel-chromium alloys which have enabled Britain to take the lead in the development of jet propelled aircraft, a lead recently emphasised by the appearance of the De Havilland jet airliner, the Comet. These alloys are manufactured by HENRY WIGGIN AND CO. LTD., on whose stand (2 G, Grand Hall) they will be displayed along with Monel, K Monel, pure nickel, Inconel, Wilco-Wiggin Thermometals and the Nilo series of nickel iron alloys. In view of the accelerated delivery now possible, the exhibits of seamless tubing will be of special interest. The development of these various nickel alloys has been the work of the MOND NICKEL CO. LTD., who will share the Wiggin stand and will show how nickel alloys can assist designers and engineers by supplying special combinations of properties for service in different fields. Examples will be given of nickel-containing materials providing resistance to heat, corrosion and wear combined with strength and ease of production. For those requiring information on nickel and its alloys, Development and Research Department staff will be available.

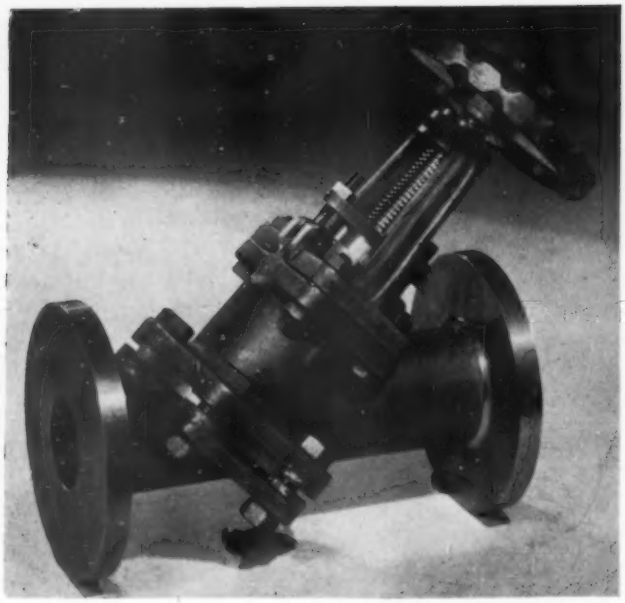
Since the last Engineering and Marine Exhibition considerable development has taken place in the manufacture and application of the nickel alloys produced by LANGLEY ALLOYS LTD. (Stand 10 W, Empire Hall), and this is particularly striking in the case of the Langalloy "R" Series of alloys. These nickel-molybdenum, nickel-chromium-molybdenum, and nickel-silicon alloys are now being widely applied in the chemical and allied process industries, including the expanding field of petro-chemicals.

Developed originally to meet the demand for materials available in this country possessing a high resistance to corrosion by such media as sulphuric, hydrochloric and phosphoric acids, their value in handling many other corrosives has been rapidly appreciated and they are now successfully handling such solutions as sodium hypochlorite, ferric and cupric salts and acidified organic solvents as well as the acids mentioned, in all parts of the world. Exhibits will include pump and valve parts,



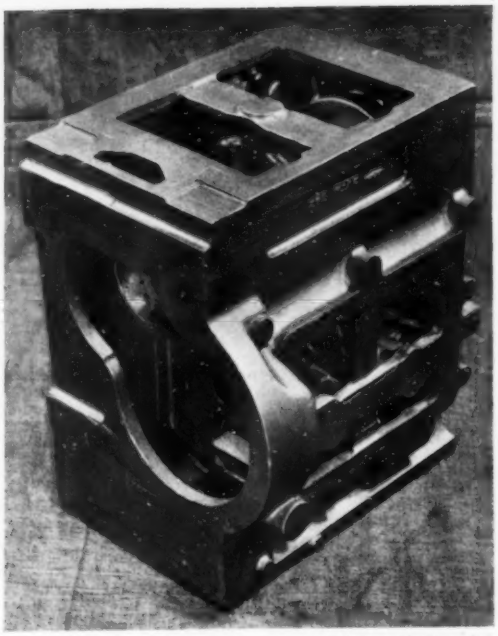
Courtesy of Langley Alloys, Ltd.

Fan for circulating hot furnace gases constructed from Langalloy 5R castings.



Courtesy of Langley Alloys, Ltd.

Langalloy 5R Y-valve.



Courtesy of Almin, Ltd.

Two-cylinder Diesel engine cylinder block casting in aluminium alloy A.C. 7.

thermometer pockets and many special castings as well as the new range of chemical valves which are now being produced not only in these alloys but also in Monel, nickel and Inconel.

In the field of copper base alloys one of the more recent developments is the manufacture of gas turbine compressor blades in Hidurax aluminium bronze. The value of these materials for this application has been appreciated for some time and now after considerable research a satisfactory combination of all the desirable properties has been attained. A special manufacturing technique is employed and results in a material with exceptionally high resistance to fatigue and corrosion, as well as high mechanical strength.

In more general applications, the high strength and good corrosion and abrasion resistance of the Hidurax bronzes is also of great advantage, exhibits including rolled bar, stampings, forgings and castings of many components used in mechanical and chemical engineering. Castings of special note are bodies and impellers for centrifugal pumps.

Also on show will be castings, stampings and bars in Hidurel 6, a high-strength copper alloy with a conductivity of at least 80% of that of hard drawn copper. It is widely used in switchgear and for resistance welding tips and wheels, where its high temperature strength is of great value. Although having a lower conductivity, Hidurel 5 has high mechanical properties, good bearing properties under many conditions and a useful resistance to corrosion. Exhibits of this alloy will include little-end bushes and valve-guides for internal combustion engines.

The Manganese Bronze and Brass Co. Ltd. (Stand 7 E, Grand Hall), founded by the late Mr. P. M. Parsons who patented manganese bronze as far back as 1876, created a new peace-time world record for propeller output in 1948. Included in the exhibits will be a replica of the patent "Scimitar" bronze propeller which has effected service improvements of 10% over designs commonly in use and has been fitted to well over 10 million tons of shipping. A small working model of the patent "Scimitar Escher-Wyss" controllable pitch propeller will also be displayed. Other exhibits will include marine shafting; stern tubes; extrusions in brass and bronze alloys; Immadium high duty bronze; Crotorite aluminium bronze; Parsons' anti-friction white metal ingots; Damaxine chill-cast phosphor bronze sticks for bearings; and the various Oilite self-lubricated materials.

On Stand 8, Inner Row, National Hall Gallery, Imperial Chemical Industries Ltd., will be showing the products of the Metals and Nobel Divisions. The central exhibit on the Metals Division Section will be a sectioned model condenser, showing the effect of corrosion and erosion on condenser tubes, and the methods recommended for preventing these faults. Other exhibits will include tubes and plates in copper-nickel-iron alloy for sea water trunking, copper and copper alloys in many forms, and a wide range of aluminium alloy products for marine applications. There will be condenser tubes in cupro-nickel, "Alumbro" (aluminium brass), Admiralty brass, "Resisco" and tin bronze with various types of ferrules. Aluminium checker plate for engine room stairways, flooring, and walkways construction will be incorporated in the floor of the stand.

Non-ferrous tubes and fittings made by The Yorkshire Copper Works Ltd. (Stand 6 F, Grand Hall) are well known to engineers throughout the world. More than 15 million Yorcalbro (aluminium brass) condenser tubes are now in service and have been fitted in more than 5,000 ships and many British and foreign power stations. The numerous interesting exhibits will include the latest marine applications, such as Yorcalbro tubes and Yorcasal fittings for hot

and cold salt water mains and pipelines; Yorkshire copper tubes and Yorkshire fittings for fresh water services, steam heating, hydraulic control pipelines, etc.; and copper-nickel-iron alloy tubes to British Non-Ferrous Metals Research Association patents, for sea water mains and pipelines.

THE BRITISH ALUMINIUM COMPANY'S stand (5 V, Empire Hall) will have as its central feature a funnel casing in aluminium alloy. Standing some 21 ft. high by 26 ft. long, it is destined for the new cross channel steamer T.S.S. *Brighton* and has been fabricated by Messrs. Wm. Denny and Brothers Ltd., Dumbarton. Made up from BA.27 aluminium alloy plate (BS/STA 7 AW, 5C) and BA.25 W and WP extruded section (BS/STA 7 AW, 10A and B), it shows a weight saving of some 4½ tons against a similar funnel in steel. Not only is the cost of upkeep of such a superstructure likely to be less than that of other materials by virtue of the high corrosion resistance, but the saving in weight at such an elevated position in the vessel allows a reduced beam and a consequent saving in power. Illustrations will be given of various applications of aluminium alloys to engineering structures while one section is devoted to an exhibit showing riveting technique. The new Rigidal corrugated aluminium sheeting and the P–G–P (positive-grip-pattern) tread-plate will also be on view. The latter is designed for such applications as engine room flooring, trench covers, walkways on cranes, and flooring for food processing plants.

A special feature of that part of the ALMIN stand (2 R, National Hall) devoted to the products of SOUTHERN FORGE LTD., will comprise two sections of an aluminium fish hold for use in trawlers. Special extruded sections act both as structural members and as a means of carrying the individual aluminium boards which make up the hold. The strength, lightness and hygienic qualities of the holds are a great advance over the old steel and wooden types and seven trawlers under construction at Grimsby are being fitted with them. In addition, a wide range of extruded sections will be displayed.

On the stand of BIRMABRIGHT LTD. (4 J, Grand Hall), examples will be shown of Birmabright alloys specially developed for marine purposes. In addition a number of the company's products will be on view on the various stands in which Birmabright has been used in the construction of ships' lifeboats and all types of marine craft.

Stand 3 CC, First Floor, Empire Hall, itself forms the exhibit of T. I. ALUMINIUM, LTD., since it is constructed of riveted sheet aluminium to simulate a deck-house and has inset a port hole and two sliding marine type windows in cast aluminium. The taffrail is formed of stanchions specially made for air-sea rescue boats and the mast carrying the T.I. symbol is an aluminium dinghy mast made by REYNOLDS TUBE COMPANY. In addition there will be a row of four other masts, ranging from 2½ in. to 7 in. in diameter. The steps up to the deck are aluminium grille type engine room steps.

The exhibits on the stand of FRY'S METAL FOUNDRIES, LTD. (4 V, Empire Hall) deal with the various materials manufactured by the company for modern soft soldering. They include soft solders; high temperature soft solders; fusible solders, etc., in the form of sticks, washers, strip, tape, ingots, rings, wire, etc., together with various types of fluxes, solder paints, creams and flux-cored wire. Emphasis is placed on the use of Fryolux solder Paint and Four-Scored solder wire, two comparatively recent developments in the field of tinning and sweat soldering which enable mass production soldering to be carried out without recourse to expensive machinery. Soldered articles will be shown and demonstration work will be carried out.

C. RYAN AND CO., specialists in brass and copper tube work for all classes of engineering, refrigerating and building work, will be showing examples of their work on Stand 5 P, National Hall. Demonstrations will be given of the method of making joints and the efficiency of the seal will be shown by pressure tests.

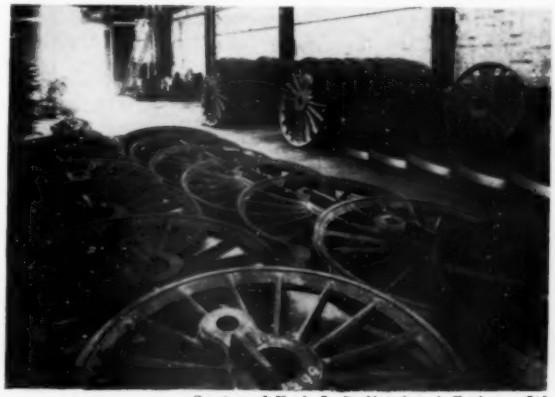
The Tandem brands of bearing alloys and white metal lined bearings, rope capping alloys, mould metals, pattern metals and die-casting metals will be shown by THE EYRE SMELTING CO. LTD., on Stand 4 V, Empire Hall, together with Esco gun metal and bronze ingots; Ariel and Esco chill cast and centrifugally cast phosphor-bronze rods; Eyre brand aluminium alloys to customers' requirements. Specimens of work carried out and castings made in these materials will also be shown, as will fluxing and tinning compounds for bearing work. One of the company's specialities on view will be Bamber's non-encrusting zincs for Leclanché cells.

THE GLACIER METAL CO. LTD. (Stand 52, Inner Row, Grand Hall Gallery) will show a comprehensive range of materials covering the needs of the engineering industry for plain bearings.

Included will be steel-backed, thin- and thick-walled white-metal and copper-lead lined bearings; bronze-backed, white metal-lined, and solid bronze, unlined, bearings and bushes; tin and lead-base white-metal die castings; standard wrapped bushes, steel-backed lead-bronze-lined, in a range of 350 English and Metric sizes; precision finished lead-bronze bars machined in the bore and on the outside diameter to assembly tolerances for bushes, thrust washers, etc.; standard phosphor bronze bars machined on the outside diameter for bushes, thrust washers, etc.

Of special interest are the Company's standard products which include a range of strip-type steel-backed white-metal-lined thin-walled engine bearings and standard bushes, steel-backed lead-bronze-lined which are offered in 350 sizes for immediate delivery. These bushes have endless applications wherever bronze bushes have been formerly used.

Various types of non-ferrous metal ingots, hydraulically compressed briquettes of scrap brass and copper, and a



Courtesy of K. & L. Steelfounders & Engineers, Ltd.

Steel castings for locomotive wheels.

variety of strippings of polythene and polyvinyl chloride from redundant cables, will be exhibited by JOHN WALTON AND CO. (CASTLESIDE) LTD., on Stand 7 HH, First Floor, Empire Hall. The Company are buyers of non-ferrous scrap metals, which are ingotted or supplied as graded scrap, and manufacturers of ingots to any required specification in gunmetal, phosphor-bronze, aluminium bronze, manganese bronze, brass, zinc and lead, all operations being under strict laboratory control.

THE ANTI-ATTRITION METAL CO. LTD. (Stand 51, Outer Row, Grand Hall Gallery) will exhibit their bronzes and white bronzes in the form of a wide variety of bearings suitable for numerous types of machinery; ingots of special bronzes, anti-friction white bronzes and chill-cast bronze sticks; locomotive slide valves; a new range of machined bushings; and electric current collecting devices for trolley buses, cranes, etc.

Anti-friction metals; steel and bronze-backed plain bearings; die finished all-white metal bearings; sintered bushes; and chill cast and cold-drawn bronze tubes and rods will be featured on the stand of THE HOYT METAL CO., OF GREAT BRITAIN, LTD. (26, Outer Row, Grand Hall Gallery), who will also display high-grade soft solders and tinning compound; Kirksite die sets; Hoyt Z.B.1 zinc-base pressure-casting alloy; low melting point tube-bending alloy; and aluminium solder.

Well-known as stockists of engineering materials, THE LONDON METAL WAREHOUSES, LTD. (Stand 8 O, National Hall) will exhibit a selection of their standard lines, including non-ferrous castings; chill-cast phosphor bronze stick; non-ferrous metals and light alloys in all forms; "Staybrite" stainless steels in all semi- and fully-fabricated forms; nuts, bolts, screws, rivets, etc. in all metals; and "Staybrite" stainless steel step plates and nosings for marine work.

Castings

RENFREW FOUNDRIES LTD., is the largest aluminium foundry in Scotland and supplies many of the famous Clydeside shipbuilding firms. On the stand of the parent company, ALMIN LTD. (2 R, National Hall), a wide range of castings will be displayed including scavenge pipes; diesel engine sumps; timing cases; manifolds; cylinder head covers; and housings. A special feature will be a show of castings used in industrial electric drills for Black and Decker Ltd.

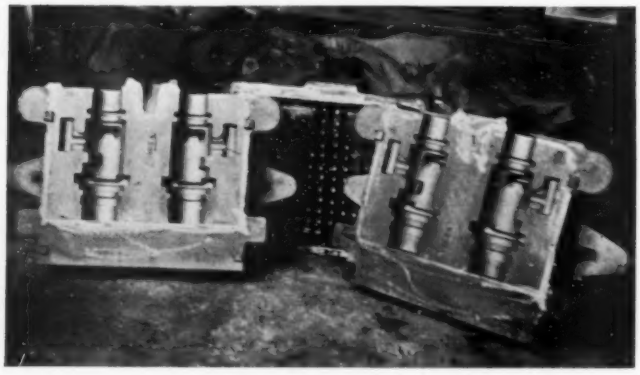
Gravity castings in brass and bronze to most standard specifications and weighing from a few ounces up to twenty pounds will be featured in the display on the stand of THE NON-FERROUS DIE-CASTING CO. LTD. (1 F, Grand Hall). Most of these castings are from moulds which have already produced many thousands of castings and an outstanding feature is the superior finish which has recently been further improved by developments in die dressings. The aluminium castings exhibited have been made in a range of alloys by both gravity and low pressure processes, those made by the latter being noteworthy for the very good definition and smooth surface. A further advantage of this process is the even grain structure and freedom from porosity which results.

The main feature of the stand of J. STONE & CO., LTD., (7 Q, National Hall), will be a full size *Queen Elizabeth* propeller with a diameter of 18 ft. 6 in. and a finished weight of 31 tons. Made of Turbiston bronze and of Heliston design, the weight of the original casting was 50 tons. Incidentally its size and weight will necessitate special lifting tackle and it will therefore have to be the first exhibit into Olympia. Other exhibits of interest will include a Stone-Kamewa controllable pitch propeller, made under licence from Sweden; a Stone's controllable pitch propeller; and a simple pendulum static balancing machine designed and manufactured by the company.

THE DAVID BROWN FOUNDRIES COMPANY, which during the war established a reputation for centrifugal castings in ferritic and austenitic steels will be exhibiting on the parent company's stand (10 V, Empire Hall), a slush pump casting representative of their wide interest in the oilfield and refineries market, and a turbine casing typifying the work the foundry is doing in the equipping of new power stations both at home and abroad. This is the first time the group has displayed at this Exhibition and a show of gears and gear boxes will be seen, an exhibit of particular interest to readers being a 4-ft. stainless steel propeller made by the Foundries Company, shown running on an oil-controlled marine reverse and reduction gearbox.

Courtesy of The David Brown Foundries Company.

Slush pump casting made in steel and weighing 13 cwt.



Courtesy of the International Mechanite Metal Co., Ltd.

Dies in Meehanite Metal for die-casting cast-iron motor-car housings.

A selection of high grade steel castings for locomotives, marine engines, turbines and a wide range of engineering purposes will be shown by K. AND L. STEELFOUNDERS AND ENGINEERS, LTD. (3 C, Grand Hall). Further exhibits will include seven sizes of Coborn cast steel anvils ranging from 14 lb. to 4½ cwt. Made from high carbon cast steel, the working face is, after machining, specially treated and hardened to give a deep tool steel face with extreme hardness and long wearing properties.

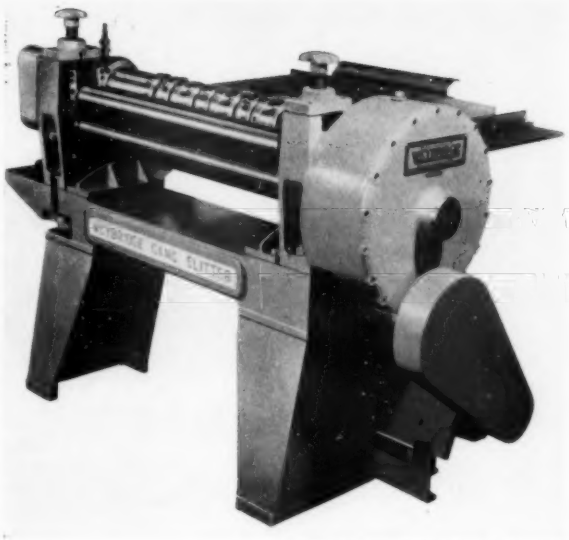
The products of the BROCKHOUSE ORGANISATION (Stand 13 B, Grand Hall) are many and varied. Included in the casting field are die castings from KAYE ALLOY CASTINGS, LTD., grey iron castings and repetition castings from R. J. HUNT, LTD.; iron castings from J. BROCKHOUSE & CO., LTD., and iron and steel castings from BROCKHOUSE CASTINGS, LTD.

Stand 8 V, Empire Hall, will house the exhibits of C. & L. HILL, LTD., founders to the trade, who specialise in castings weighing from 1 oz. to 1 ton in all non-ferrous specifications. A varied range of such castings will be shown, including heat-treated aluminium alloy castings for use in radar equipment; aluminium gravity die castings; and the Hilchil chill-cast phosphor bronze.

THE TECHNICALLY CONTROLLED CASTINGS GROUP was formed in 1946 to market high quality castings in all metals under the trade name of Teconic. There is no proprietary process inherent in the trade name, the high quality being maintained by continuous technical control and inspection procedures which are subject to the general oversight of an independent firm of consultants. The constituent firms are LAKE & ELLIOTT, LTD., S. RUSSEL & SONS, LTD., ALEXANDER SHANKS & SON, LTD., SHOTTON BROS. LTD., HENRY WALLWORK & CO., LTD., and JOHN WILLIAMS & SONS (CARDIFF) LTD. Displayed on Stand 14 J, Grand Hall, will be a representative range of Teconic castings in grey and alloy iron, carbon and alloy steel, whiteheart and blackheart malleable iron and non-ferrous alloys. The display includes jobbing and repetition work weighing from a few ounces to more than a ton.

Well to the fore in the development of the centrifugal process for iron castings, THE SHEEPBRIDGE STOKES CENTRIFUGAL CASTINGS CO., LTD. (Stand 12 H, Grand Hall) will be displaying a selection of cylinder liners in the Centricast range of alloys including Loded Centricast, Austenitic Centricast; and Centrard nitrogen-hardened material. Centricast liners chromium hardened by the British Van der Horst process will also be on view. Of special interest to those concerned with corrosion and heat resistance, castings centrifugally cast in metal dies and in sand moulds, together with castings statically cast in sand moulds, will be shown in the Corrosalloy corrosion resisting steels, the Thermax heat-resisting steels and the Corrosist nickel-base alloys. Centricast iron castings are made for use in the manufacture of piston rings, cylinder liners, bushes, etc., and the superiority of castings produced by this method will be seen from a display of components made from them. Other exhibits will include a range of static castings in grey and alloy irons; die cast iron rod; filters, oil retaining bearings and bushes made by powder metallurgy; and valve seat inserts made from special centrifugally cast alloy iron castings.

The name "Meehanite Metal" is applied to a group of high-duty cast irons, nearly thirty in number, each of which is manufactured, under a strict system of control, to possess certain properties and characteristics which



Courtesy of George Cohen, Sons & Co., Ltd.

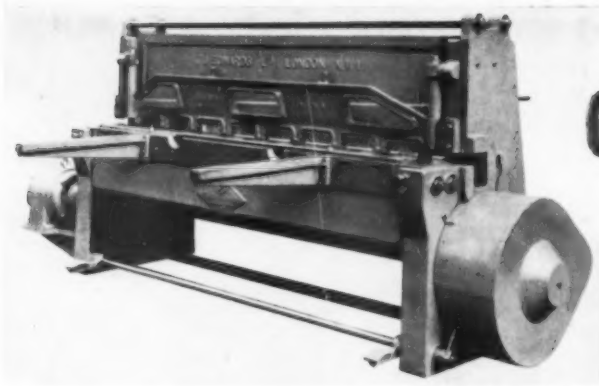
The Weybridge light gauge gang slitting machine.

will make it suitable, in the highest degree for meeting some specific service requirement. The stand of THE INTERNATIONAL MEEHANITE METAL CO., LTD. (13 E, Grand Hall) will be laid out so that the engineer can see the uses of Meehanite metal castings for all types of industry—actual castings taken from normal production and photographs and charts demonstrating its uses. Technical advice on the uses of Meehanite metal may also be obtained on the stand. A miscellaneous selection of machine moulded, high grade Meehanite metal castings will also be shown on Stand 4 N, National Hall, by THE BUTTERLEY CO., LTD.

Plant and Equipment

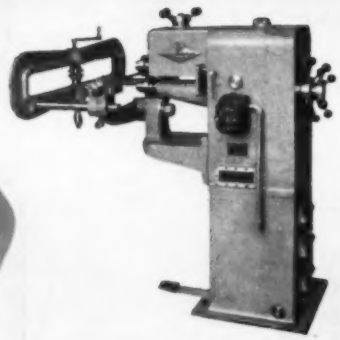
THE INCANDESCENT GROUP, which will be exhibiting on Stand 2 S, National Hall, comprises THE INCANDESCENT HEAT CO., LTD., METALECTRIC FURNACES, LTD., CONTROLLED HEAT AND AIR, LTD., SELAS GAS & ENGINEERING CO., LTD., and METAL PORCELAINS, LTD. A complete range of photographs will be shown, illustrated by the use of models, covering metallurgical, furnaces and ancillary equipment for all industries, fired by solid fuel, gas, oil and electricity. The range includes complete plants for vitreous enamelling; bright brazing and annealing; galvanising, normalising, hardening and tempering; gas carburising; and malleableising. Also represented will be complete mechanised sheet and strip rolling mill equipment; foundry equipment; arc melting furnaces; continuous and static drying ovens for all processes, including tin-printing and core and paint drying; gas and oil burners and valves; air-gas mixing apparatus; aluminium melting furnaces; laboratory heating equipment; vitreous enamel frits; oxides, etc.

Engineering exhibits on the stand of REDIFFUSION, LTD., (13 V, Empire Hall) will include industrial radio frequency heating of both induction and dielectric types. Demonstrations of radio frequency heating will be given frequently throughout each day on the stand.



Courtesy of F. J. Edwards, Ltd.

Besco production guillotine—model 48–10 fitted with an automatically operated sheet hold-down.



Courtesy of F. J. Edwards, Ltd.

Besco production rotary combination machine.

Since 1938 the industrial use of gas has increased by more than 70%, but there is scope for even wider developments in the use of this fuel and on Stand 2 A, Grand Hall, THE GAS COUNCIL will have an information bureau where those interested can discuss their problems with experts on the subject. A pictorial display will illustrate some of the engineering uses of gas, including forging, metal cutting, metal melting and heat treatment. Among the exhibits will be a small laboratory-type gas-fired muffle furnace, larger versions of which are used industrially ; a model of a gas-fired lip-axis tilting furnace for metal melting ; and samples of the products of gas-fired forging and heat-treatment furnaces.

The Specialities of BARLOW-WHITNEY, LTD. (Stand 8 C, Grand Hall) cover a wide range of electrically heated plant and apparatus for industrial processes. The size of certain larger units and special installations precludes their display, except in the form of photographs. Among the exhibits will be seen a medium sized industrial oven with forced air circulation ; a small general purpose furnace for heat-treatment operations up to 1,100° C. ; a 500 lb. (nominal capacity) melting pot suitable for lead, babbit, tin and stereo metal ; a 75 lb. pot suitable for the babbitting of car engine bearings ; and a commutator soldering machine.

On Stand 3 M, National Hall, A. E. W., LTD., will be exhibiting a range of electric heat-treatment furnaces which have been designed for a long, highly-efficient life. The maximum temperature for which they are suitable is 1,250° C. Also to be seen will be low-temperature industrial ovens and Klipin miniature circuit breakers.

Notable among the exhibits of GEORGE COHEN, SONS & CO., LTD. (Stand 1 L, National Hall) will be the Weybridge gang slitting machines in light (30 in. × 22 s.w.g.), medium (36 in. × 8 s.w.g.) and heavy (18 in × 8 s.w.g. stainless steel of 45 tons/sq. in. tensile strength) sizes. These geared machines are suitable for slitting Stalloy, brass, tin plate and other materials. The feed table is removable to permit the use of coiling and decoiling equipment. The machine can be fitted with detachable cutter shafts, which are removable without disturbing the cutter arrangements and cutters may be ground in position by means of a portable grinding attachment. Also of special interest will be the redesigned Coborn-Wadley D.E.P.S. 24 combined punching, shearing, cropping and notching machine and its two new satellites, the Coborn-Wadley S.E.S.C. 24 single-ended power shearing, cropping and notching machine and the Coborn-Wadley S.E.P. 24 single-ended power punching machine. Other exhibits will include the Coborn Type "R" Guillotine shearing machine, the Type "R" plate bending rolls and the Type "R" all-steel press brake.

Shaping machines will comprise the major exhibit on the stand of C. H. JOYCE, Ltd. (6, Outer Row, Grand Hall Gallery). These will include 18 in. and 24 in. machines of conventional design and a 24 in. hydraulic machine. Also displayed will be a 6 in. quickcut high speed hack sawing machine.

VICKERS-ARMSTRONGS LIMITED (Stand 9 F, Grand Hall) and its associated companies are concerned with a range of widely diversified products covering many of the basic equipment needs of the modern world in shipbuilding, heavy and light engineering and aircraft. It is, of course, obviously impossible to include a specimen of each of the products in the confined space of an exhibition stand, but a series of interesting photographic

Courtesy of The Morgan Crucible Company.

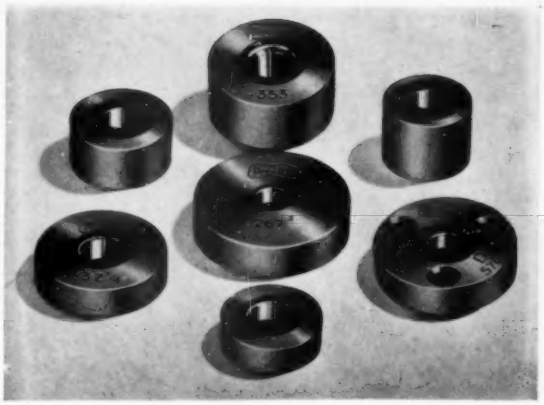
Morgan hydraulic tilting furnace pouring into a plumbago mould via a plumbago tundish.

enlargements show some of the larger productions while, in addition to models of British clearing presses, and variable speed gears, a representative selection of equipment for the soap, ink, paint, box-making and brewery trades is exhibited.

The exhibits on Stand 2 E, Grand Hall, will be of particular interest to the sheet metal working and allied industries. F. J. EDWARDS, LTD., will be showing there, three machines new to the Engineering and Marine Exhibition. The first is the Besco production guillotine, model 48–10, which is fitted with an automatically operated sheet hold-down and has open-ended side frames to allow sheets of unlimited length to be trimmed. The other two new machines are the Besco production press brake and the Besco production rotary combination machine. The latter is suitable for swaging, wiring, jennying, strip and circle cutting, flanging edging, and any other operation where a rotary motion of the roll spindles is required. Other exhibits on this stand will include a selection of sheet metal working machines from the Besco range including nibbling machines; a punching, shearing, section cropping and notching machine; folding machines; guillotines; swaging machines; bar bending machines, etc.

Those seeking information on compressors, fans, and heating and ventilation systems will find much of interest on the stand of KEITH BLACKMAN, LTD. (11 P, National Hall). Amongst the exhibits of particular interest to readers are three types of blower suitable for providing air service to producers; cupolas; furnace hearths; oil and gas burners; and for gas boosting. A number of fans suitable for exhausting noxious fumes during industrial operations will also be on view, together with air filters and space heaters suitable for workshops and factories. Among the specialised exhaust fans may be mentioned a self-contained unit for exhausting grinding dusts and one for exhausting fumes from arc welding.

One of the recent developments of THE MORGAN CRUCIBLE CO., LTD. (Stand 12 E, Grand Hall) is a rotary crucible furnace designed for the economical melting of swarf and metal powders; the principle of operation will be illustrated by a working model. Other furnace exhibits include the Morgan bale-out furnace fitted for the first time with thermostatic control; a self-contained miniature crucible furnace, using paraffin as a fuel and capable of melting 32 lb. of brass in 25–30 minutes; and the Morgan hydraulic tilting crucible furnace. The tilting axis of the last-named passes through the point of pour so that the work remains stationary throughout the pour. Among the plumbago exhibits will be tun-dishes; skimmers; stirrers; phosphorisers; plunger-mixers; self-skimming crucibles; stoppers and nozzles for steel ladles; bricks and shapes for steel ladle and other lining; launders; knock-off riser plates; muffles; and moulds. The principal advantages of plumbago are its high thermal conductivity, its refractoriness, its resistance to thermal shock and abrasion, and the fact that it is not wetted by molten metals. Morganite carbon engineering components to be seen will include products for the electrical mechanical and engineering industries. Morganite bearings fall into five classes—carbon; metallised carbon; graphite bronze; bronze and iron; lead bronze. Impervious carbon tubes for heat exchangers handling corrosive fluids will be displayed along with Carblox chemical linings and Carblox carbon hearth blocks and linings. Nor is the research worker overlooked; pure oxide ware in alumina, recrystallised alumina, magnesia, zirconia and thoria will be exhibited in the form of pyrometer sheaths; furnace



Courtesy of Protolite, Ltd.

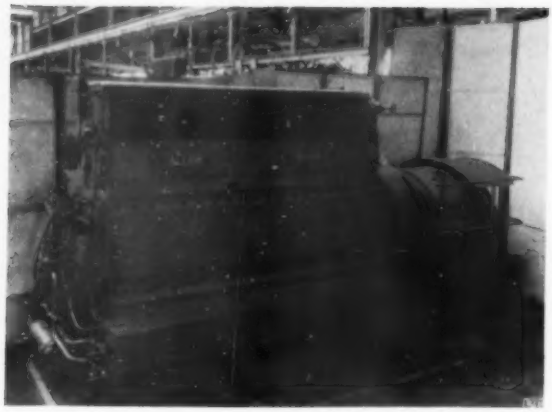
Prolite cemented tungsten carbide dies.

Courtesy of S. Wolf & Co., Ltd.

Newly introduced W.D. 4c. drill fitted in drill stand (Type E.S. 23) in operation as a powerful drill press.

Courtesy of The Consolidated Pneumatic Tool Co., Ltd.

Pneumatic impact wrenches in use in a railway workshop.



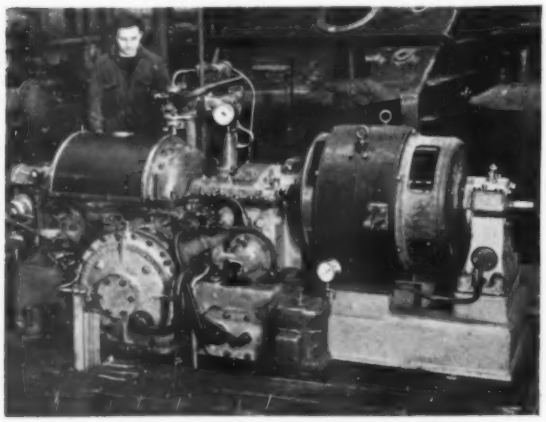
Courtesy of W. H. Allen, Sons & Co., Ltd.

180 kw. marine auxiliary Diesel engine generating set.

tubes and muffles ; special muffles ; melting containers contact supports, etc.

Small Tools

Portable power-driven tools, operated by both compressed air and electricity will be demonstrated by the CONSOLIDATED PNEUMATIC TOOL CO., LTD., on Stand 4 W, Empire Hall. The C.P. range provides mechanical aids for almost every job formerly done by hand and a number of tools will be shown on the kinds of job they are regularly doing in shipyards, engineering shops, mines and civil and general engineering work. Of special interest will be the recent additions to the range. Foremost amongst these is the C.P. reversible impact type pneumatic wrench for tightening and removing nuts with amazing ease and efficiency. Another exhibit of increasing interest is the range of Hicycle electric drills, grinders and polishers which operate on a low voltage and at 200 cycles per second frequency. They have speed and power unequalled in similar sized tools and also enable savings on power consumption to be achieved. C.P. Universal electric tools for operation with standard voltages will also be displayed along with air



Courtesy of C. A. Parsons & Co., Ltd.

50 kW. steam turbo-generator designed for educational purposes.

compressors, wire-brush machines and other products of the company.

On Stand 39, Inner Row, Grand Hall Gallery, C. & J. HAMPTON, LTD., will be exhibiting an extensive range of Record tools, including Stillson pipe wrenches ; chain pipe wrenches ; pipe cutters ; pipe vices ; bolt clippers ; and mechanics', fitters' steel and combination vices. Special attention is drawn to the improved pattern Record bolt clipper which has drop-forged steel handles and shorter adjusting arms giving greater strength and durability. A further interesting exhibit will be an improved type of flooring cramp which embodies several new features.

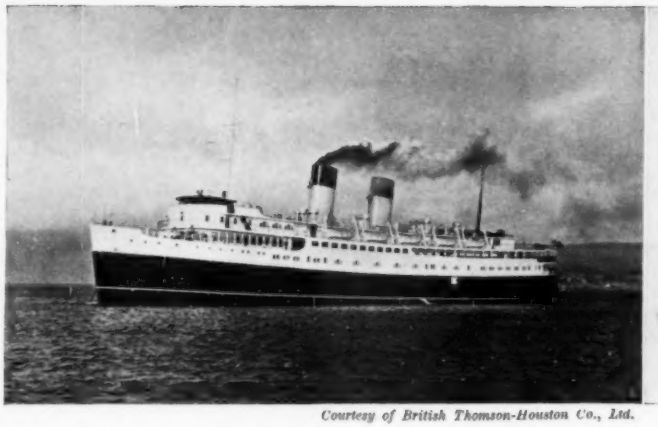
A complete range of engineers' cutting tools will be exhibited by FIRTH BROWN TOOLS, LTD., on Stand 7 H, Grand Hall, including drills ; reamers ; milling cutters ; end mills ; " Zeelock " serrated blade milling cutters ; type 3 inserted blade cutters tipped with " Mitia " carbide and involute gear cutters. The application of " Mitia " carbide for a wide range of purposes will also be shown, together with butt-welded high speed steel lathe tools ; high speed steel tool holder bits ; ground thread taps ; ground thread chaser dies (radial and tangential) all types of screw thread tools ; high speed steel metal slitting saws and screw slotting cutters. " Insto " segmental type circular metal cutting saws ; machine knives for wood ; high speed steel cutter block knives ; shear blades, rivet snaps and punches ; cold chisels ; engineers' files and saw files ; hacksaw blades ; circular and bandsaws for wood ; and running (live) centres will also be shown. The " Millenicut " and " Dreadnought " milled files will be in use on steel, cast iron, copper, brass and other non-ferrous materials.

LEYTONSTONE JIG & TOOL CO., LTD., on Stand 1, Inner Row, Grand Hall Gallery will display a complete range of Leytool hand tools, including precision hand drills ; combination breast drills ; ratchet spanners ; universal joint spanners ; four-bladed screwdrivers, mechanic's kit of ratchet spanners ; endless hacksaw ; ratchet socket sets and ratchet-plug set for socket head screws. The company also specialise in the design and manufacture of jigs and tools for mass production purposes and the exhibits will include press tools ; jigs and fixtures ; moulds ; gauges ; special purpose machines ; manufactured components and service tools.

The scope of Perpro cemented carbides will be indicated on the stand of PRODUCTION TOOL ALLOY CO., LTD. (61, Inner Row, Grand Hall Gallery) by the exhibits which will include tipped lathe tools for machining ferrous and non-ferrous metals ; tipped lathe centres ; milling cutter heads with Perpro tipped blades ; form tools, dies for cold heading, extrusion and special purposes ; Perpro tips to British and Continental standards ; and special tools as used for the production of jet engines.

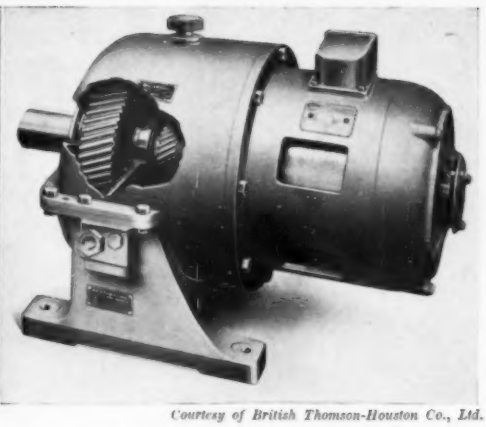
PROTOLITE, LTD., which is a subsidiary of Murex, Ltd., will show, on Stand 16, Centre Row, National Hall Gallery, a selection of cemented tungsten carbide tips and tipped tools, die pellets and dies for all purposes and wear resisting parts. Pure tungsten and molybdenum rod, wire, sheet and strip will also be displayed.

Readers with a fixing problem will find much of interest on Stand 6 K, Grand Hall, where the RAWLPLUG CO., LTD., will probably be displaying the solution. For heavy plant, Rawlbolts enable fixing to be achieved without the time lag of waiting for cement to dry.



Courtesy of British Thomson-Houston Co., Ltd.

6,000 ton C.P.R. passenger ship "Princess Marguerite," fitted with B.T.H. turbo-electric propulsion equipment.



Courtesy of British Thomson-Houston Co., Ltd.

B.T.H. double-reduction geared motor unit.

Rawlanchors, toggles and the Rawlnut anti-vibration device are useful for fixing to thin and hollow materials and suitable devices are available for under-water service. The Durium drill now makes drilling in masonry as easy as in wood and demonstrations of Rawlplug electrical and pneumatic tools will show how holes up to 2 in. diameter can be cut into the hardest material quickly and accurately.

A. H. RITCHIE & Co. (Stand 8, Centre Row, National Hall Gallery) will exhibit drills; files; reamers; screwing tackle; hacksaws; precision tools; Rennie tipped and butt welded tools; vices; silver steel; and ground flat stock; also displayed will be drilling machines; filing machines; lathes; and electric drills; grinders; screwdrivers; and blowers.

The complete range of WOLF electric tools will be displayed on Stand 4 P, National Hall, and will comprise electric portable drills; screwdrivers; grinders; polishers; sanders; blowers; chisel mortisers; hammer kits; also a range of engine reconditioning equipment including valve seat grinders and valve and engine servicing kits, valve refacers and the "Mobilectric" engine workshop. The display will include newly introduced models of the Universal Heavy Duty Drills, types WD4c, WD5, WD5c, WD6 and WD6c, the GL3 portable electric Lathe Grinder for external and internal grinding and two new valve seat grinding kits. For the special benefit of overseas visitors practical demonstrations of machines will be given by qualified technicians.

Electrical Equipment

In this section the main items are motors and electrical equipment suitable for industrial use, although mention is made of certain exhibits of general interest.

The exhibits on Stand 1 D, Grand Hall, include a varied selection of independent and combined units representing W. H. ALLEN, SONS & CO's comprehensive range of steam turbines, steam engines, Diesel engines, pumps, generators, motors and control gear. The main exhibits will comprise a 750 kW. Awlinwun self-contained marine type- turbo-generator; a six cylinder, 150 kW. Diesel engine generating set; and a 60 kW. steam engine generating set; as well as various sizes of vertical and horizontal motor driven pumps. Several of the motors used are of the totally-enclosed, ventilated, drip-proof type. The pumps are of interest in view of the materials employed in cases where corrosive waters are to be dealt with; these include Staybrite, Hidurax I, and Monel. Cupro-nickel is used for the slip rings of a 176·5 kVA. alternator to prevent contamination from the atmosphere. Other exhibits include motors and electrical control gear.

On Stand 5 N, National Hall, THE BRITISH THOMSON-HOUSTON COMPANY is exhibiting marine propulsion and auxiliary equipment; Mazda lamps and lighting equipment; and electrical plant for various industrial applications. B.T.H. marine radar will be shown on the stand of Dobbie McInnes Ltd. (6 E, Grand Hall). B.T.H. are well known for their pioneer work on electric ship propulsion by turbo-electric and A.C. and D.C. Diesel electric systems. Although space prevents representation by exhibits certain details from a current contract will be shown.

Among the exhibits of plant for industrial use are electric motors of various kinds up to 40 H.p., including lift and flameproof motors, a 3-H.p., geared-motor unit, fractional horse-power motors, and geared-motor units of the fractional horsepower type.

A working demonstration of "Emotrol" (electronic

Courtesy of Metropolitan-Vickers Electrical Co., Ltd.

The M.G.B. 2009 on trials in the Solent.

motor control) is a fascinating and instructive exhibit. The equipment, which uses thyratrons for controlling the speed of a D.C. motor, provides automatic speed regulation to within + or — 2% over a wide speed range, current limit control, acceleration at constant current, and dynamic braking. The unit operates on A.C. mains, and no rotating machinery, other than the motor is required. When fine speed control is necessary, "Emotrol" panels can be supplied to maintain motor speeds within limits of + and — 0·2%. Other exhibits include a Thruston operating a workshop crane brake mechanism suitable for a motor of about 60 h.p.; a selection of Fabroil gears; and various types of compressor.

A representative range of alternating current electric motors from 0·25 to 200 h.p. for machine drives will be displayed on BROOK MOTORS stand (21, Outer Row, Grand Hall Gallery). Protected and totally enclosed surface cooled motors in standard enclosures or for flange mounting directly on the machine will form the main range, while low centre motors for the woodworking and bootmaking industries will be included. For the machine tool maker, stator and rotor units in sizes from 0·5 to 30 h.p. are available. The new range of light control gear will be demonstrated, including a cavity mounting model specially designed for incorporation in machine casings.

For light machines, refrigerators, etc., the range of "Cub" f.h.p. motors from 0·25–1 h.p. will be offered in various types such as flange or resilient mounting, protected or totally enclosed.

The main exhibit of BROOKHIRST SWITCHGEAR, LTD., on Stand 53, Inner Row, Grand Hall Gallery, is an operating flow diagram control board for Messrs Lever Bros., Ltd., Port Sunlight. It demonstrates how precise information about the flow and storage of material can be given at a remote central station by means of visual flow indication. Control is initiated at the board, push-buttons and control switches being built into the mimic flow lines. Other exhibits include multi-motor control boards being supplied for the heating and ventilation system of the re-built House of Commons; automatic electrically-operated soot blowers for boiler plant; hand-operated and automatic starters; push buttons; limit switches; and control switches.

The size of JOHN BROWN & CO., LTD.'s products on Stand 11 G, Grand Hall, necessitates their display by means of models. Those of the 83,673 ton Q.S.T.S. *Queen Elizabeth* and of her propulsion machinery will be of general interest. Readers will be particularly interested in two gas turbine models, both of John Brown-Escher Wyss closed cycle type. The 12,500 kw. plant to be installed at Dundee for peak load relief is oil-fired and the small 620 kw. unit is intended to utilise the waste heat in hot gases from the coke ovens in the Foleshill Gas Works, Coventry. In both of these, use is made of the latest commercially available creep-heat resisting alloys. In many ways the application of materials in closed cycle gas turbines differs from that in jet engines. For instance, weldability has an important bearing on the choice of creep resisting alloy and has been the subject of extensive tests by the Company and its associates.

Some interesting new developments can be seen among the electric motors exhibited by BULL MOTORS (Stand 4 Q, National Hall). The exhibits are representative of the firm's wide range of industrial A.C., super-silent and fractional horsepower motors. An outstanding lift motor development seen for the first time at the exhibition is the new heavy duty model of the Bull Super Tandem motor, fitted with an independent cooling fan which, running continuously increases the performance from the normal duty to the heavy duty class.

CROMPTON PARKINSON'S LTD. (Stand 5 W, Empire Hall), are exhibiting their Parkinson A.C. motors. A 5 h.p. screen-protected squirrel-cage induction motor, with the end shield partly cut away to show the winding, can be compared with a similar power "Klosd" squirrel-cage induction motor similarly exposed. In both motors a positive ventilation system is incorporated, the fan blades being integral with the rotor in the screen-protected type, and in this way local hot spots are prevented. In the case of the Klosd model, this method enables the size and weight to be much less than with a plain totally enclosed motor.

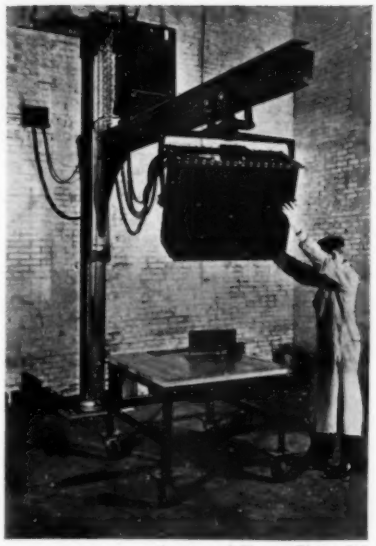
Featured on Stand 10 P, National Hall, will be DORMAN & SMITH LTD'S. switchgear, including a marine type switchboard and a metalclad switchboard typical of their unit principle assembly. Flameproof switchgear and marine and industrial lighting fittings will also be exhibited.

THE ELECTRICAL POWER ENGINEERING CO. (B'HAM), LTD., on Stand 4, Centre Row, Grand Hall Gallery, will be showing a sectioned ½-h.p. flameproof motor for pumping solvents and a sectioned 7½ h.p., 72 volt D.C. battery traction motor. Other exhibits will include totally enclosed motors, flameproof motors, watertight motors and drip proof motors. Of special interest will be the flameproof marine type propeller fan motor designed for working in an airstream with the terminal box displaced from the motor.

A wide range of electrical machines will be displayed by THE ELECTRO DYNAMIC CONSTRUCTION CO., LTD., on Stand 2 N, National Hall and Stand 11, Outer Row, National Hall Gallery. The exhibits will include totally enclosed and drip proof vertical and horizontal motors and generators; flameproof and torpedo type fan motors; D.C. variable speed motors; A.C. commutator motors; and fractional horse power motors. Hand and automatic control gear including examples incorporating electronic devices. An interesting exhibit is a fully automatic 1½ k.w. petrol electric generator, supplying A.C. and D.C. output. The engine is switched on when the load reaches 40 watts and continues until it falls to 30 watts.

Among the exhibits of the LANCASHIRE DYNAMO & CRYPTO, LTD., and associated companies on Stands 6 and 7 W, Empire Hall, will be many types of A.C. and D.C. motors and motor units including flameproof, drip proof and "Gasworks" types, the latter being suitable for outdoor service. A planer motor generator set, loom motors and small and f.h.p. industrial motors will also be seen together with geared motor units ranging from ¼–50 b.h.p. Commercial mercury arc rectifiers ranging from outputs of a few kilowatts up to equipment for sub-stations and Varionic control equipment incorporating grid controlled mercury arc rectifiers will be shown by the NEVELIN ELECTRIC CO., LTD. on these stands whilst CRYPTON EQUIPMENT, LTD. will include amongst their exhibits a 1,500 amp. oil-cooled electroplating rectifier.

The first vessel to be propelled at sea by a gas turbine was the M.G.B. 2009 in which one of the three Packard reciprocating engines was replaced by a Metrovick gas turbine which will be shown on THE METROPOLITAN-

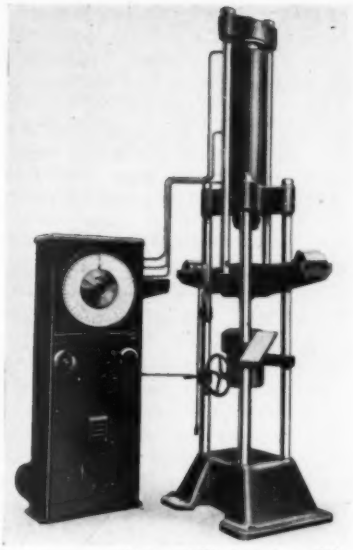


Courtesy of Newton Victor, Ltd.

Newton Victor 250 kv. shockproof industrial X-ray unit.

Courtesy of Gamma-Rays, Ltd.

Gamma-ray operating container for radium or radon seed. (Open during exposure).



Courtesy of W. & T. Avery, Ltd.

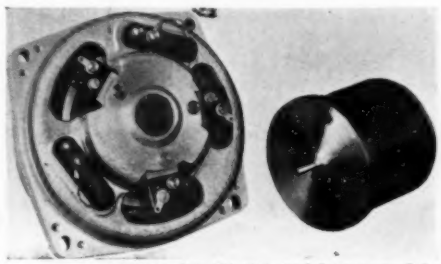
50-ton self-indicating universal testing machine.

VICKERS ELECTRICAL COMPANY'S stand (16 H, Grand Hall). It comprises a gas generator consisting of a compressor, combustion chamber and a turbine driving the compressor followed by a power turbine coupled by reduction gear to the propeller shaft. A speed of 20 knots was attained on the gas turbine only and with the two Packard engines 33 knots, or 1·5 knots more than with the three Packard engines, was attained. Other exhibits include Seascan radar equipment; motors; generators; control equipment; and a miniature oscilloscope with a front panel no larger than a post card.

NEWMAN INDUSTRIES, LTD. (Stand 7 P, National Hall), specialise in the production of totally enclosed, fan cooled squirrel cage induction motors for all purposes. Exhibits will include foot and flange mounting types of industrial motors which range up to 25 h.p.; totally enclosed loom motors; flameproof motors; the Newman Imp F.H.P. motors; and a range of push-button contactor type starters.

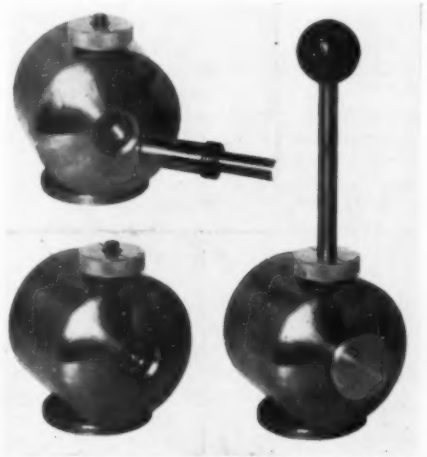
The main exhibit on the stand of C. A. PARSONS & Co., LTD. (8 E, Grand Hall), will be a 50 k.w. turbo-generator of the type the company is presenting to universities in different parts of the world. These machines have been constructed for educational purposes and are designed as far as practicable on similar lines to large commercial units. As a contrast, photographs will show commercial machines ranging from 2,000 k.w. to 50,000 k.w. capacity. The electrical side of the firm's activities will be represented by a 150 kVA. distribution transformer, 3-phase, 50 cycle, 11,000/440 volt. indoor core type unit, whilst a nine-foot high pyramid on which will be mounted silvered glass reflectors in sizes ranging from 5½ in. up to 36 in. diameter will show the products of the optical side of the company. Examples of machined turbine parts, turbine blading, high voltage electrical conductors and insulating material will be displayed in an illuminated showcase.

PHILIPS ELECTRICAL, LTD. (Stand 16G, Grand Hall) are showing their new Motronic equipment for the control



Courtesy of Smith's Industrial Instruments, Ltd.

Heavy type transmitter and receiver for the Desynn system of remote indication.



Courtesy of Salus-Schall, Ltd.

Exposure container for radio-active material shown ready for carrying (right): with source turned into firing position (bottom left); and with source removed for insertion into small apertures (top left).

of D.C. motors by electronic means from an A.C. supply. It is applicable to such equipment as wire and thread drawing plant, where it is required to maintain a constant speed regardless of load ; lathes where the equipment can replace most of the gearing and where on machining disc faces the speed is proportional to the tool position ; and in wind-up drives where it is generally necessary to compensate for the increase in spool size so that the tension of the material being wound is constant.

Instrument and Testing Equipment

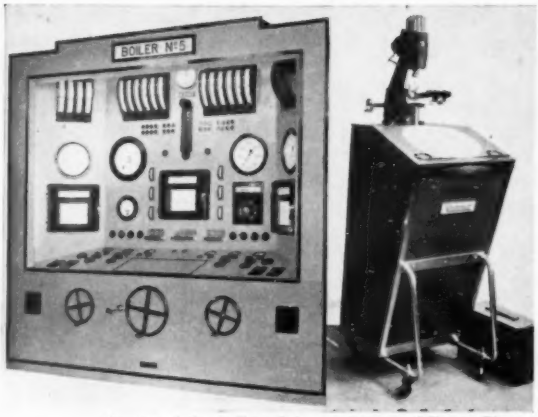
Those readers who are interested in the mechanical testing of materials will be able to see, on Stand 3 H, Grand Hall, the latest machines in the range manufactured by W. & T. AVERY, LTD. The exhibits will include a compression testing machine of 100 tons capacity ; two dynamic fatigue testing machines ; a Rockwell type hardness tester ; a Brinell type hardness tester ; a cement testing machine ; an impact testing machine for plastics ; a self-indicating universal testing machine, capacity 50 tons ; and a dynamic balancing machine. Other items displayed concern the range of weighing scales for which the firm is noted.

Hardness testing machines will also be seen on Stand 7 H, Grand Hall, where FIRTH BROWN TOOLS, LTD., will be showing variable and fixed load Hardometer testing machines and on Stand 9 F, Grand Hall, where the Vickers Pyramid hardness testing machine will be exhibited by VICKERS-ARMSTRONGS, LTD.

SAMUEL DENISON & SON, LTD., Stand 3 GG, First Floor, Empire Hall, will be showing mechanical testing equipment and weighing machines. Included in the former will be a Model T45 creep testing machine based on an N.P.L. design and of 5 tons capacity. It will be shown with furnace and optical measuring equipment using a Marten's-type minor extensometer. For preliminary survey work on small specimens of high temperature materials the Model T47, ¾-ton machine will be shown in which the creep measurements are made by dial gauge. In addition a Model T42U dial indicating universal testing machine of 12,500 lb. × 20 lb. capacity will be shown. This machine has three sub-capacities representing half, fifth and tenth of the maximum.

Stand 53, Outer Row, Grand Hall Gallery, represents the activities of two associated companies—COMMERCIAL X-RAYS, LTD., & GAMMA RAYS, LTD. The former specialise in industrial X-ray applications and are equipped for carrying out radiography of components at their works or on site. A new feature of their operations is a Welder's Testing Service which is operated on a contract basis. Whereas X-rays are limited to a penetrating capacity of 3 in. of steel, the radiation from radioactive materials can penetrate up to 9 in. and Gamma-Ray, Ltd., specialise in this application. In addition to carrying out gamma-radiography they will advise on the best source for a particular purpose and supply the requisite storage and operating equipment.

For those interested in carrying out their own radiography by X-rays, the stand of NEWTON VICTOR, LTD. (1 X, Empire Hall), will be of interest. The exhibits will include a 140 kV. set and a 250 kV. set together with a selection of industrial radiographic accessories. Both have oil immersed X-ray tubes and in the 250 kV. set the tube is in the same container as the high voltage transformer, thus eliminating high tension cables. The thickness of steel which can be penetrated is 1½ in. and 2½–3 in. for the 140 kV. and the 250 kV. sets respectively. For the 250 kV. set stationary jib-crane mountings for



Courtesy of George Kent, Ltd.
A typical Kent boiler instrument panel for a large power station.

Courtesy of Venner Time Switches, Ltd.
Venner projector.

laboratory work, and mobile jib-crane assemblies for shop-floor operations are marketed by the company as well as specially designed mountings for boiler radiography. Photographs will illustrate a 2 million volt. set recently installed at the works of Babcock & Wilcox, Ltd. Although radium will penetrate several inches of steel, exposure times render it impracticable beyond about 4 in. and the use of higher steam pressures has therefore demanded X-ray equipment capable of examining welded joints in material up to 12 in. thick. The better known application of radiography is in non-destruction testing but it has perhaps an even greater function to perform in the foundry, as the use of radiography will often help to improve foundry technique to the point where scrap is negligible.

On Stand G 16, Grand Hall, PHILIPS ELECTRICAL, LTD., will be exhibiting a complete range of X-ray equipment for the industrial user. "Macro" 150, 200 and 300 units, with which it is possible to examine steel up to 2 in., 3 in., and 4 in., respectively, will be exhibited together with a full range of dark room and radiographic accessories. X-ray diffraction apparatus, radiation detectors, monitoring equipment and photographs of the electron microscope, will also be displayed.

Amongst other exhibits such as mobile X-ray sets, magnetic crack detectors and accessories for radiography, SOCLUS SCHALL, LTD., on Stand 4 M, National Hall, will be exhibiting a new type of exposure container for radio-active material which reduces the risk to the operator to the absolute minimum. The container is made in two sizes, for 250 mg. and 500 mg. of radium respectively, and is of heavy tungsten alloy.

The new BERCO/BPT automatic voltage stabiliser, of particular interest to the electronics engineering field will be shown by THE BRITISH ELECTRIC RESISTANCE CO., LTD., on Stand 12, Outer Row, National Hall Gallery. The stabiliser will supply a constant output voltage—vital for the satisfactory performance of any electronic apparatus—despite variations in the load or load power-factor and normal frequency variations, whilst the output wave form distortion is negligible. The stabiliser is based on a motor-driven Regavolt infinitely variable transformer, controlled by a voltage sensitive relay, giving an output voltage stable to ±1%. The resistances and rheostats shown will include vitreous enamelled resistors, industrial and laboratory type sliding resistances ; rotary type toroidally-wound

rheostats and potentiometers ; heavy duty resistors for welding duty and water tight and hermetically-sealed resistances for shipboard use.

THE DRAYTON REGULATOR & INSTRUMENT CO., LTD., on Stand 3 B, Grand Hall, will be showing instruments for measuring, recording and controlling temperature, pressure and draught. The temperature instruments use either a vapour tension or a mercury-in-steel thermostatic system, the former up to 180° C. and the latter up to 500° C. Small geared electric motors and Hydroflex metal bellows will be among the exhibits on this stand.

ELLIOTT BROS. (LONDON), LTD., on Stand 21, Outer Row, National Hall Gallery, will be displaying examples of instrumentation. Selected instruments will be featured on a number of panels and these will include the Elliottronic high speed potentiometer recorder (3 secs. across chart) ; the Elliott pneumatic control system which consists of the Elliott Pneulec electro-pneumatic transformer to convert electrical signals into proportionate pneumatic signals and the Elliott Trimod pneumatic controller producing proportionate integral and rate functions ; indicating and recording flowmeters ; CO_2 and $CO+H_2$ indicators and recorders ; and humidity and temperature indicators and recorders. The Elliott remote transmission system can be used to advantage in many applications for the indication of various quantities over distances ranging from a few yards to many miles. Of particular interest to the iron and steel industry will be the application of Elliott magnetic amplifiers to liquid steel temperature measurement, thus enabling the thermo-couple signal to drive a large internally illuminated indicator. The pyrometric exhibits will include an optical pyrometer outfit ; portable total radiation pyrometer equipment ; and a representative range of foundry, furnace and engine pyrometer stems.

Eversheds Electro-pneumatic process controls will be a feature on the stand of EVERSHED & VIGNOLES, LTD. (6 Q, National Hall). A simple pilot plant will be installed to demonstrate recent developments in this class of process control apparatus and instruments on view will include a new stainless steel high pressure flow meter ; a new design of displacer type liquid level transmitter ; the Eversheds electro-pneumatic valve positioner ; a precise level controller ; and three-term electric controllers (for proportional, integral and derivative control). A number of new Eversheds disc type recorders will be shown for the first time in connection with this demonstration. Other remote indication and control equipment will also be exhibited. In the Servo mechanism field of precision electronic Servo units and high performance Servo motors associated amplifiers and quick response chart recorders will be on show.

A special feature of the stand of GEORGE KENT, LTD. (3 E, Grand Hall) will be working models of further developments of the Mark 20 air-operated automatic controller. These include air transmission, devices for the remote adjusting of the setting point of a controller, ratio leverages and origin shifting devices.

An exhibit of particular interest is a flow ratio controller comprising a Kent " K.M." type flow meter fitted with a Mark 24 air transmitter sending an impulse to the setting pointer of a second K.M. flow meter, fitted with a Mark 20 air-operated automatic control.

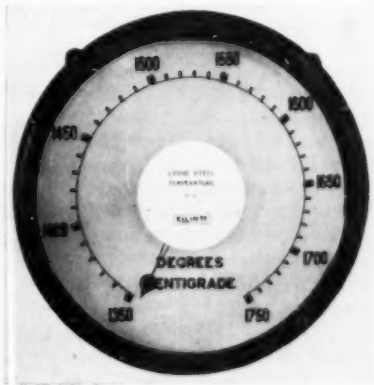
Other working models include a ring-balance flow controller fitted with Mark 20 air-operated control mechanism and a Multelec pH. recorder. Meters for liquids and gases will also be shown, including potentiometric instruments for temperature, CO_2 and electrical conductivity.

On Stand 29, Inner Row, National Hall Gallery, SMITH'S INDUSTRIAL INSTRUMENTS, LTD., will be exhibiting tachometers, including new types of electrical models ; pressure, vacuum and compound gauges ; marine clocks and thermostats ; and stop watches. The Desynn system of remote indication will also be displayed. This is particularly suitable for the distant indication of pressure, force, displacement, temperature, fluid level, etc., and consists of a transmitter and an indicator, operated from a 12 or 24 volt. D.C. supply.

VENNER TIME SWITCHES, LTD. (Stand 11, Inner Row, Grand Hall Gallery), will display the firm's range of meters ; time switches ; timers ; delay relays ; and clock movements. Of special interest to mechanical and production engineers will be the indicating gauges ; electrically-controlled stop watches and the Venner contour projector which may be used under normal lighting conditions.

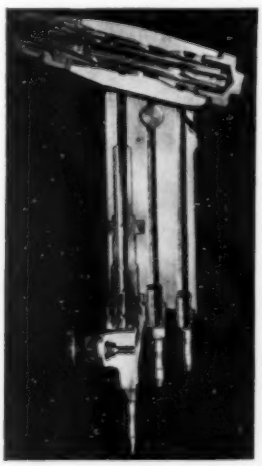
Large illuminated liquid steel temperature indicator for mounting in a central position in the melting shop.

Courtesy of Elliott Bros. (London), Ltd.



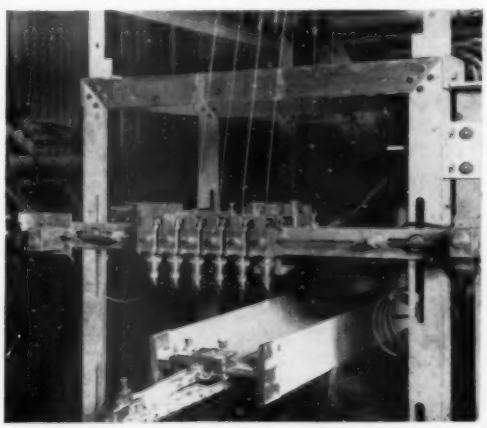
Sectioned Schori metallising process pistol.

Courtesy of Schori Metallising Process, Ltd.



Automatic metal spraying plant.

Courtesy of Metallisation, Ltd.



Miscellaneous

ALBRIGHT & WILSON, LTD. (Stand 44, Inner Row, Grand Hall Gallery) will be showing, on the one hand, water treatment for boiler feed and cooling water and other purposes, and on the other, a range of silicone products including fluids for damping and hydraulic systems; compounds—heat-stable water repellent insulating materials, for sealing high tension ignition systems and high frequency equipment, for use as mould release agents and foam inhibitors; greases—special lubricants for valves and bearings operating at exceptionally high and low temperatures; resins and varnishes—which are heat-resistant and waterproof; and Silastic rubber—which remains serviceable over a very wide temperature range.

THE DARLINGTON INSULATION CO., LTD., which has been formed to carry out the contract work for the Chemical & Insulating Company will, be displaying on Stand 56, Outer Row, Grand Hall Gallery, a model of the boiler built for the new Portobello generating station which will be insulated by the company. Insulation products exhibited will include Darlington 85% magnesia for temperatures up to 650° F.; Meta-dextramite, up to 1,200°F. and Dextramite, up to 2,000° F.

Descaling and water treatment are the principal problems concerning CLENSOL, LTD., exhibiting on Stand 12, Outer Row, Grand Hall Gallery. The display will include photographs and samples showing deposition and corrosion as experienced in pipe lines and boiler and condenser tubes and also the method of prevention or removal by the Clensol process. Chemical mixtures and processes for the removal of oil, grease and slime from waterways and steam passages will also be shown.

THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, in which is centralised a large part of the research carried out by the British Government will show some of the engineering research undertaken by its own Research Establishments and allied Research Associations, on Stand 3 U, Empire Hall. Included in the exhibits will be a standard dead-weight hardness testing machine for standardising test blocks; a 300-ton load gauge for compression tests utilising electrical resistance strain gauges; stages in the manufacture of electrical resistance strain gauges; a six spindle wear testing machine; work on problems associated with the use of fuel; engineering and industrial applications of cast iron and nodular cast iron, in co-operation with the British Cast Iron Research Association, who are working on the question of cavitation erosion as it affects the cast iron propeller; work on the behaviour of welded steel frame structures, welded pipe lines and pressure vessels, fatigue testing of welded structures, and the development of weldable high strength structural steels by the British Welding Research Association; and a working model of the reversing gear developed by Pametrada for gas turbines. Films to be shown will deal with cavitation erosion and load-testing of welded structures.

MEK-ELEK ENGINEERING, Ltd., on Stand 3 A, Grand Hall, will display their range of Mekelite industrial lighting units which have been developed as a result of long experience in this class of work.

On Stand 1 A, Grand Hall, METALLISATION, LTD. will be demonstrating the spraying of all metals by their process and samples will also be displayed. Exhibits will include various models of spray pistols together with samples of everyday work. Details will be available of the new automatic plant, illustrated in this article.

THE METALOCK Stand (1 BB, First Floor, Empire Hall) will display a number of photographs of recent

Courtesy of Crompton Parkinson, Ltd.

Welding studs on a transformer tank by the Nelson "gun."

successful repairs of fractures in heavy machinery by the Metalock process. Several castings repaired by Metalock will also be shown.

Time lost by the contraction of dermatitis, as a result of contact with industrial irritants, mitigates against our economic recovery. On the ROZALEX stand (54, Inner Row, Grand Hall Gallery), will be shown a full range of barrier preparations which provide complete protection against almost every known irritant. Also exhibited will be the Rex dispenser for ensuring a controlled, economic and uncontaminated supply to each person and Rozalex ointment for conditioning the skin.

SCHORI METALLISING PROCESS, LTD. (Stand 1 P, National Hall), will exhibit equipment for metal and plastic spraying by the powder method which is the only method for plastics which does not employ solvents. Plastic exhibits include sprayed Polythene and Thiokol for protection against chemical and erosive attack. The Schori patent shot blasting equipment and accessories will also be on view.

The rust-proofing and paint-bonding processes developed by THE WALTERISATION CO., LTD., will be covered by the exhibits on Stand 25, Outer Row, Grand Hall Gallery. The preparation of metals for painting is being given increasing attention at the present time as the realisation of its importance grows. Of particular interest is the preparation developed for brushing-on where the material cannot be immersed, as in the case of structural steelwork.

WELDING EXHIBITION

The Welding Exhibition, which is incorporated in the Engineering and Marine Exhibition, will be housed in the annexe to the Grand Hall at Olympia.

THE BRITISH RESISTANCE WELDING MACHINE MANUFACTURERS' will occupy a joint Stand, 21 A, Grand Hall, where they will display examples of products fabricated by resistance welding, with details of the production times and the saving of steel which result from the use of the methods. Exhibits will vary from projection welded saucepans to spot-welded aircraft jet engine assemblies; and from butt-welded aluminium cycle wheel rims to heavy flash butt-welded rail track. For the guidance of those interested there will be present, engineers from the constituent firms:—HOLDEN & HUNT, LTD., SCIAKY ELECTRIC WELDING MACHINES, LTD., BRITISH FEDERAL WELDER & MACHINE CO., LTD., METROPOLITAN-VICKERS ELECTRICAL CO., LTD., A. I.

Electric Welding Machines, Ltd., Siemens-Schuckert (Gt. Britain), Ltd., Philips Electrical, Ltd., and Meritus (Barnet), Ltd.

Welding cables with tough flexible rubber insulation will be shown by British Insulated Callenders Cables, Ltd., on Stand 14 E, Grand Hall, in the main exhibition.

The British Oxygen Co., Ltd. (Stand 15 E, Grand Hall) will have a number of working exhibits, which will include two argonarc welding booths; two gas welding benches; a 55 in. cutting machine; a 36 in. cutting machine; a portable straight line cutting machine; and a plate edge preparation cutting machine. Among the static exhibits will be found powder cutting equipment; Unionmelt welding process equipment; flame hardening equipment; C.P.U.300 Argonarc welding unit; Cutogen

Courtesy of Fusarc, Ltd.

Fusarc deck welders in operation.

hand cutters; and Argonarc torches, Marks II, III and IV.

Nelson stud-welding equipment will be exhibited on the main stand of Crompton Parkinson, Ltd. (5 W, Empire Hall). Weighing only 5 lb. the Nelson "gun" is designed for use by semi-skilled labour and is capable of welding studs and pins from 10 s.w.g. to $\frac{3}{4}$ in. diameter. The arc welding of steel studs by this method results in greatly increased production and is being used in the ship building, and engineering industries.

On Stand 14 D, Grand Hall, Cyc-Arc, Ltd., will have on view a comprehensive range of stud-welding equipment and accessories. This will include the A/20, range $\frac{1}{8}$ in. to $\frac{7}{16}$ in., and designed to operate on 200/240 vo't A.C. supply with a maximum current of 2 amp, and the B/20, range $\frac{5}{16}$ in. to $\frac{7}{8}$ in., for 400/440 volt single-phase A.C. with the same maximum current. The A/20 equipment incorporates the recently developed "Pilot Arc" system which eliminates the difficulties in welding on scaled, rusty or greasy surfaces or those with a moderate coat of paint. Other recent developments on show will include the E/I automatic stud-welding controller; an electro-hydraulically operated welding head; a portable hand welder; and a completely self-contained stud-welding machine tool.

On the automatic side of fusion welding the exhibits of Fusarc Ltd., on Stand 12 C, Grand Hall, will be of interest. The process has recently been approved by Lloyds for Class I pressure vessel welding and a large number of machines have been supplied to shipyards and engineering works both at home and abroad. Equipment is now made for dealing with almost any sized article from 2 in. diameter up to 20 ft. diameter, and up to lengths of 100 ft. or more. An outstanding feature amongst the range of exhibits will be the "Marine" deck welding equipment, a compact automatic welding head, mounted on a power-operated mobile carriage.

A range of arc welding electrodes will be exhibited by Invicta Electrodes, Ltd., on the stand of the Owen Organisation (8 V, Empire Hall).

The Johnson Matthey exhibit, on Stand 12 D, Grand Hall, will take, in the main, the form of a combined display of their low temperature brazing alloys and the resistance welding products of their associates, Mallory Metallurgical Products, Limited. For brazing, a new and versatile material, Easy-flo No. 2, is announced which is lower both in cost and melting point than the widely known original Easy-flo, and has excellent physical properties.

The Mallory fluted electrode, which provides, without change in price, a 70% increase in cooling efficiency and proportionately greater working life, is another innovation which may be seen. An exact comparison between the heat-transference capabilities of these and conventional electrodes will be shown by a bench model.

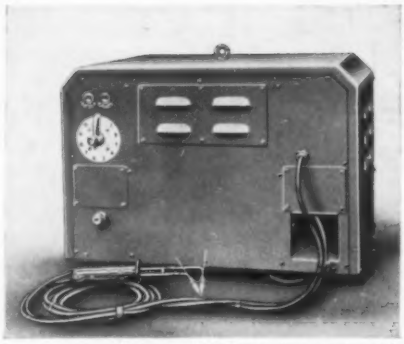
On Stand 12 K, Grand Hall, a large range of Lincoln arc-welding accessories will be on view including several recent developments. These include the I.N.S. holder, the new MFS fully moulded face shield with protective handgrip, and the R.C.M. cable connector. The electrodes will include Fleetweld 5, now used almost exclusively on pipe-line and oil refinery work throughout the world. The SA 150 motor generator will also be on view, and welding engineers will be available for

Courtesy of Johnson Matthey & Co. Ltd.

The brazing of copper return bends on to a refrigerator evaporator.

consultation any time during the exhibition. Technicolour films will be showing almost continuously on the daylight screen.

Among the arc-welding generators and accessories to be seen on the stand of MAX-ARC WELDERS, LTD. (17 K, Grand Hall), will be an interesting small, compact A.C. arc welder for the light engineer, the Max-Arclette. Providing a current range of 15–150 amp. in 24 steps, it is suitable for electrodes up to 8 gauge. Also included in the exhibits will be the twin carbon electrode holder for welding very light gauge metals which are too thin for normal arc welding. This twin carbon torch is suitable for connecting to all types of A.C. welder.

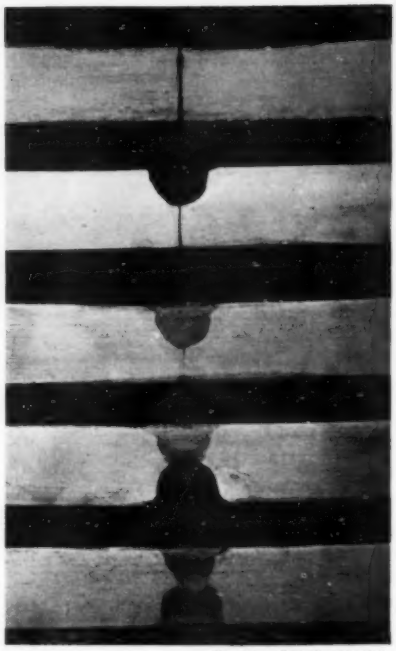


Courtesy of Metropolitan-Vickers Electrical Co., Ltd.

50 amp. (.15 kVa.) atomic hydrogen welding set.

Hand-welding equipment to be shown on Stand 11 C, Grand Hall (METROPOLITAN-VICKERS ELECTRICAL CO., LTD.), will include the Paradyne D.C. and the Thermac A.C. single welder sets; an atomic hydrogen set; accessories; and electrodes. Demonstrated exhibits will comprise a 2-ton motor-operated manipulator; an automatic-atomic-hydrogen welder; and an automatic arc welder. The last named is an example of electronic control of the deposition of weld metal. The electronic control is arranged to regulate the feed of the electrode to suit variations in the arc length and the closeness of the control makes possible the use of a short arc, a high rate of deposition, and thus a high welding speed.

Several new developments will be shown by MUREX WELDING PROCESSES, LTD., on Stand 11 F, Grand Hall, and practical demonstrations will be given. One of the most interesting exhibits will be the latest 300/400 amp. diesel engine driven equipment fitted with cartridge starter. Other welding sets include a 150-cycle alternator set having an output of 300 amps. for each of four operators; a 250-amp. moving core regulator; a 175-amp. transformer set. The new Murex Safety device, which automatically reduces the voltage at the electrode holder from the normal 80–100 volts to a safe value of 30 volts, within a fraction of a second of breaking the arc, will be shown fitted to a 250-amp. portable transformer set. Also exhibited will be the new Type S electrode holder and the extensive Murex range of electrodes.



Oxyarc flame gouging was used in the preparation of both sides of these plates.

Courtesy of Rockweld, Ltd.

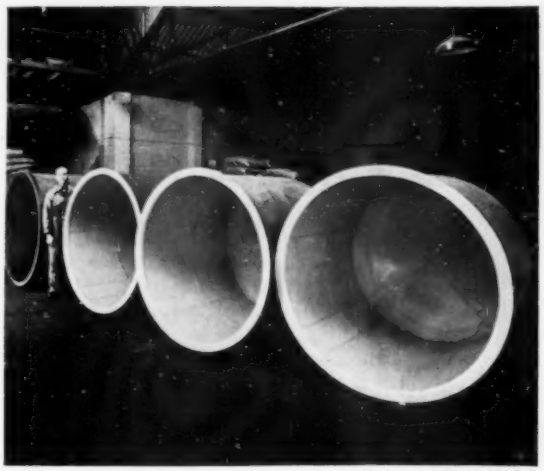
Courtesy of Rockweld, Ltd.

Cutting an alloy steel digger bucket by the Oxyarc process.

PETBOW, LTD., will be showing, on Stand 13 F, Grand Hall, a selection of portable engine driven welding plant and transformer sets. Of the former there will be a lightweight 300-amp. single operator set; a heavier set of the same output; a 400-amp. single operator set; and a 300-amp. two operator set. All the transformer sets, for 200, 300 and 400 amps. are oil cooled and fitted with built-in power factor condensers. A range of electrodes and new equipment will also be displayed.

The Lion Electrodes shown on the Stand of G. D. PETERS & CO., LTD. (17 A, Grand Hall), will include mild steel grades for general purposes, and special types for high tensile structural steels, castings and maintenance work as well as a range for hard surfacing applications. In addition, there will be a full range of electrodes for the welding of stainless steels, cast iron, aluminium and bronze. Demonstrations will be provided by means of A.C. equipment of the oil-cooled transformer type with the addition of the latest design of H.F. ionising unit for special light-gauge and non-ferrous work and by a D.C. combined unit. A portable I.C. engine driven D.C. set will also be on view together with a number of operator's accessories.

An interesting exhibit on Stand 16 G, Grand Hall, (PHILIPS ELECTRICAL, LTD.), is a welding rectifier, a dual current set with an A.C. output suitable for electrodes up to 6 gauge and on the D.C. side, up to 12 gauge. Alloy and non-ferrous electrodes can be used as well as the carbon arc. The lower range on the D.C. side is useful for sheet metal work on account of the exceptional



Courtesy of Rockweld, Ltd.

Vessels made by welding plastics.

suitability of the rectified current. Also to be shown is a portable A.C. plant suitable for fabrication and repair work. The unit is small and compact, with an output of 200 amp., intermittent rating. A range of the latest electrodes will also be displayed.

The cutting of stainless steel by flame methods presents difficulties not encountered with mild and low alloy steels. The problem is, however, of increasing importance in the manufacture of chemical plant and the heavier type of gas turbine plant. One of the solutions to this problem will be shown on Stand 14 F, Grand Hall, where ROCKWELD, LTD., will be demonstrating their new Oxyarc process using tubular electrodes. The special characteristics of the process in the fast piercing and cutting of various metals, and in gouging and rivet removal are also of particular interest in repair work. The application to gouging has been further developed by a new electrode not yet on the market. Also exhibited, will be a new electrode holder which fits into an insulated socket at the end of the cable; it can, therefore, be withdrawn when the welder leaves his work without fear of arcing occurring. A display of welding plant, electrodes and fabricated components will complete the normal welding exhibits but an exhibition of welded polythene and P.V.C. will evoke considerable interest as these materials are light, tough and inert to a large range of chemicals, the possibilities opened up by welding can easily be envisaged.

Courtesy of Safety Products, Ltd.

Safety goggles.

In welding as in grinding, chipping and similar operations, the protection of the operator's eyes is of first importance and attention is directed to the stands of J. & R. FLEMING, LTD. (16 K, Grand Hall), and SAFETY PRODUCTS, LTD. (22 A, Grand Hall) for displays of goggles, face shields and protective clothing.

New All-Aluminium Bookstall

THE recent opening of the new all-aluminium bookstall of Messrs. W. H. Smith and Son Ltd., at Marylebone Station is particularly interesting for it indicates "the shape of things to come" so far as future "W.H.S." bookstall design is concerned. It has several unique features and is believed the only design of its kind in the country.

General view of the new all-aluminium bookstall at Marylebone Station.

Built to replace a former wooden structure, the new bookstall is semi-circular in plan, 25 ft. diameter and 11 ft. high and is designed to give the maximum possible counter and display space. The external metalwork is in aluminium with a pleasing satin finish in natural colour: the whole is fabricated in sections for easy and quick assembly or dismantling. The architectural features are finished in the same metal. The internal fittings are partly constructed of aluminium alloy and partly of plastic.

The shape is interesting. It is semi-circular with a fine sweep of counter. At one end is a special "walk in" book section, where book buyers can examine books without being hustled and jostled by newspaper customers at the counter. The fascia is a translucent opal panel with inset red plastic lettering and illuminated from behind by fluorescent lighting. The light is reflected down from the underside of the projecting fascia canopy through fins into the magazine line.

The whole of the aluminium used in the construction was produced by The British Aluminium Company Ltd. The stressed members are in BA.25 alloy (AW.10) and the unstressed members in commercially pure aluminium. Designed by H. F. Bailey, L.R.I.B.A., the bookstall was fabricated in the works of J. Starkie Gardner Ltd. and transported to the site in sections.

Continued from page 208.

costs make it highly desirable for furnace campaigns to be lengthened and stoppages for repairs to be reduced. For all these reasons the demand for more durable refractories has been continuous. Yet these demands have to be met by the refractories industry, when it, too, is suffering from a decrease in the availability of some of its best quality raw materials. It is obvious that this situation can only be met by continued research.

EXTRACTION, ALLOYING AND FABRICATION OF MAGNESIUM

By Major C. J. P. Ball, D.S.O., M.C., F.R.Ae.S.

In this paper the author comments briefly upon the remarkable progress achieved during the last 25 years over the whole field of extraction, alloying and fabrication of magnesium and its alloys, which has made this metal readily available to engineering designers and constructors at prices and in quantity which were thought impossible of attainment in so short a time. The greatly improved mechanical properties, both at room and elevated temperatures, and in particular the outstanding improvement in workability and reliability of the latest magnesium-zirconium alloys, serve to emphasise even more strongly the potential importance of magnesium and its alloys to Britain in particular, and to all those other parts of the Commonwealth which at present have to rely upon supplies of aluminium imported from hard currency countries.

The element magnesium in its various compounds is widely distributed throughout the earth's crust. It is estimated that the upper stratum, to a depth of some two miles, contains an average of 3·45% magnesium oxide, making it the fourth most abundant metal. The most valuable of the ores used are magnesite or magnesium carbonate, and dolomite. Sea water contains about 0·13% of magnesium in the form of salts, principally chlorides and sulphates. Magnesium is found in the deep brines of Michigan; in the Strassfurt deposits it is present as carnallite, which is also now being recovered in substantial quantities from the Dead Sea.

The author gives particulars of plants in Britain for the production of magnesia and describes the electrolytic processes for extracting the magnesium and also thermal reduction methods. In view of more recent developments he gives particular attention to the alloying of magnesium and to applications.

Until quite recently the elements most widely used for alloying with magnesium have been aluminium, zinc and manganese; aluminium and zinc as hardeners, to improve the physical properties, and manganese to improve corrosion resistance. Recently, however, after prolonged study and considerable experimental work a magnesium-zirconium range of alloys have been developed which are of outstanding interest. This range of alloys is more fully described in the January and February, 1947, issues of this journal.

RECENT PROGRESS IN THE METALLURGY OF COPPER AND COPPER ALLOYS

By Maurice Cook, D.Sc., Ph.D., F.I.M.

The consumption of copper continues to increase and world usage has risen from about 1,700,000 tons in 1928 to 2,400,000 tons in 1947, the proportions derived from Empire sources being 7 and 20% in these two years, respectively. The last two decades, which is approximately the period broadly reviewed in this paper, with naturally a greater emphasis on more recent years, have witnessed substantial progress in improvement in plant, manufacturing processes, and techniques, in the introduction of new processes, in the improvement of the quality and standard of products, and in the development of new products and new alloys.

New types of melting furnaces, particularly electric, have been employed to an increasing extent throughout the industry. Low-frequency induction furnaces are now a characteristic feature of large manufacturing units in the wrought section of the industry and early plants of 600 lb. capacity have been added to or replaced by furnaces of up to 2,500 lb. capacity. In addition to melting methods and their control, advances have been made in foundry techniques, and a marked improvement in the quality of bronzes and other alloys resulted.

There have been greater changes in plant and techniques for the production of sheet and strip, in the period reviewed, than in most other major manufacturing operations. Larger mills of greatly improved design have come into use for processing larger ingots and billets; and the use of mechanical methods has greatly increased in rolling mills. Innovations in rolling and annealing have not only had a marked beneficial effect on the economics and efficiency of production by the saving of power, labour and materials, as well as increasing output, but they have raised the standard of quality of the product.

Tubes are now generally produced from solid billets by an initial hot-working process, such as piercing or extrusion, and the use of cast hollow billets has only continued for those alloys which cannot be hot worked. Considerable improvements have been effected in tube drawing methods which have increased productivity. In wire manufacture the broad trends of development have been in increased speed of drawing and all that goes with it in the form of improved machines, larger coils, and more mechanical methods of handling.

On improvements in established materials the author said said that some 20 years ago only tough-pitch coppers were generally available in wrought or fabricated forms, although there was, and still is, on the basis of consumption, quite a range of these materials regularly produced, including high-conductivity copper of high purity as well as several less pure grades and special grades. While copper of tough-pitch quality is suitable for many applications, the presence of oxygen and subsequent liability to "gassing" is a disadvantage, as, for example, in welding. The need for copper which is not liable to "gassing" led to the development of deoxidised copper, which has been commercially available in Britain since about 1920. Of the many elements and compounds tried as deoxidants phosphorus is most commonly used, but the presence of as little as 0·05% phosphorus reduces the conductivity to 60% of that of high-conductivity copper. The production of high-conductivity oxygen-free copper, commenced some 17 years ago is a major development. It is produced from cathode copper and the melting and pouring arrangements, involving the use of neutral gases, are so designed that the molten metal is not exposed to air or oxygen. The production of high-conductivity oxygen-free copper from cathodes without resource to any melting operation has also been investigated and demonstrated.

A considerable amount of investigational work has been carried out on copper alloys and a considerable review is given of developments in this field.

MICROANALYSIS
CHEMICAL AND PHYSICAL METHODS
APPARATUS · METALLURGICAL · APPLICATIONS · TECHNIQUE

OUR articles on the sub-micro balance will have given some idea of how thoroughly manual dexterity must be developed by the aspiring sub-micro worker. Some recent practical experience in the construction and use of a sub-micro balance has brought this home with added force to the present writer. One assembles masses of quartz fibres, many of them so fine that unless observed in a favourable light they are invisible. A fibre laid down in the wrong place is probably a fibre lost. In fact, one is forcibly reminded of the initial instruction in the classical recipe—" First catch a hare !" Here, having caught one's fibre, one must then catch another, and one must then proceed to join these cobwebs so as ultimately to produce a quite complex beam assembly. This raises a query as to whether manual dexterity, a sine qua non *in the analytical or micro chemist, does not, in many cases, require to be reinforced by an adequate standard in some, at least, of the five senses. Certain operations of the microchemist make severe demands on eyesight which is not reasonably good. In the same way, it is asking a lot to expect a colour blind analyst to reproduce his end-points. While the extent to which most chemists rely on a curiously selective sense of smell is probably not fully realised. It is our feeling—we may be wrong—that too little attention is paid, in assessing aptitude or possible aptitude for analytical work, to the demands which it is possible, in individuals, for the five senses to meet.*

Amperometric Titration

Part IV—Some Preliminary Experiments on the use of 8-Hydroxyquinoline *

By J. T. Stock

(*Chemistry Department, L.C.C. Norwood Technical College, Knight's Hill, London, S.E.*27)

The titration of cadmium alone, or in the presence of copper or zinc, is described

Titration of Cadmium

The amperometric titration of cadmium with 8-hydroxyquinoline has not previously been described. Titration of a pH 5·0 buffer that was $2{\cdot}5 \times 10^{-3}$ M with respect to cadmium yielded heavily-rounded curves and low results. Since the pH was below the value of 5·66 given by Fleck[17] as the lower limit for the complete precipitation of cadmium, the failure was not unexpected. On raising the pH of the supporting solution to 6·0, the reasonable titration curves shown in Fig. 3 were obtained. Since, however, the rounding in the region of the end point is much more than that obtained with copper under comparable conditions, titration at extreme dilution is not possible and the reproducibility is not so high. Typical results are given in Table II.

TABLE II.—TITRATION WITH 5×10^{-3} M 8-HYDROXYQUINOLINE SOLUTION OF 1-ML. PORTIONS OF ACETATE pH 6·0 SUPPORTING SOLUTION CONTAINING CADMIUM

Temp. = 13 – 16°; E_a = −0·9 volt. Interval between additions, 3–4 min.

Cadmium Conc., $\times 10^{-3}$ M	Titres, ml.	
	Theor.	Obsd.
2·5	1·000	0·996
1·75	0·700	0·702, 0·697
1·25	0·500	0·497, 0·501
0·75	0·300	0·298, 0·295

Copper and Cadmium Together

Although pH 6·0 lies within the range of reported complete precipitation of both copper and cadmium, the obvious difference in the solubilities of the precipitates suggested that the titration of copper in the presence of cadmium might be accomplished. That copper and zinc may be successively titrated with quinaldinic acid[2, 18, 19] gave support to this idea. As is clear from the results given in Table III, this proved to be the case. Co-precipitation, if any, did not exceed the experimental error. Similar remarks apply to titrations performed in sodium potassium tartrate medium.

It should be emphasised that the results obtained do not in any way conflict with those of Fleck and Ward. In amperometric titration, the operator is able to follow the course of the precipitation and thereby to adjust suitably the rate of addition of reagent. Gravimetric determination, on the other hand, perforce requires an excess of reagent. According to Fleck and Ward,[13] zinc may be completely precipitated at a pH as low as 4·58. Accordingly, the success in titrating zinc in

* Concluded from p. 179.

17 Fleck, H. R., *Analyst*, 1937, **62**, 378.
18 Stock, J. T., *Chem. Products*, 1944, **7**, 23.
19 Stock, J. T., *Analyst*, 1947, **72**, 291.

TABLE III.—TITRATION WITH 5×10^{-3} M 8-HYDROXYQUINOLINE SOLUTION OF COPPER IN THE PRESENCE OF CADMIUM OR ZINC.
Temp. = 11 – 16°; E_A = –0·4 volt. Interval between additions, 3–4 min. Volume of sample, 1 ml

Concentration, × 10^{-2} M.				Titres, ml	
Copper	Foreign Ion	Foreign Ion	Medium	Theor.	Obsd.
1·50	1·00	Cadmium	Acetate	0·600	0·600
0·75	1·75	,,	,,	0·300	0·299, 0·302
1·75	0·75	,,	Tartrate	0·700	0·702, 0·700
0·75	1·75	,,	,,	0·300	0·298
1·50	1·00	Zinc	Acetate	0·600	0·613
0·75	1·75	,,	,,	0·300	0·352
1·75	0·75	,,	Tartrate	0·700	0·698
1·25	1·25	,,	,,	0·500	0·507
0·75	1·75	,,	,,	0·300	0·318

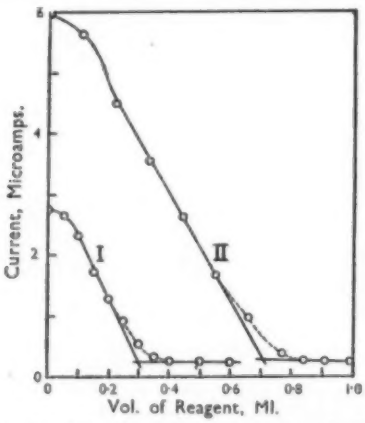


Fig. 3.—Titration of 1 ml. of cadmium solution with 5×10^{-3} M oxine solution. Cadmium concentrations, × 10^{-2} M :— Curve I, 0.75 ; II, 1.75.

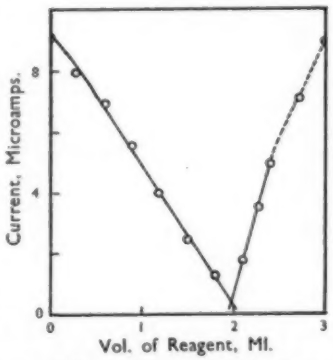


Fig. 4.—Titration of 10 ml. of 2.5×10^{-3} M zinc solution with 25×10^{-3} M oxine solution.

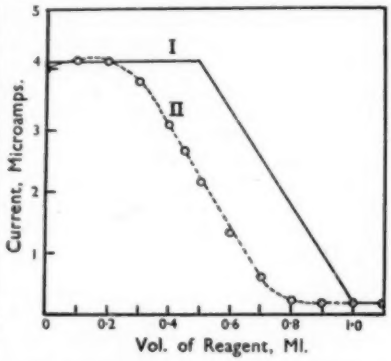


Fig. 5.—Attempted stepwise titration of zinc and cadmium. Curve I, theoretical ; II, observed.

solutions buffered at pH 5·0 was not unexpected. A typical titration curve is shown in Fig. 4. At the applied e.m.f. of –1·4 volt used in this case, both zinc and the reagent are electroreducible, so that the current first decreases to the end point and then rises again. Whereas the polarographic wave of zinc exhibits a region of almost constant diffusion current at the applied voltage in use, that of the reagent has a steeply-rising slope, so that the current is not accurately proportional to the concentration. Accordingly, the distortion of the rising branches of the curves is merely as expected. Nevertheless, by taking more readings rather nearer to the end point region than is usual, good results are obtainable. Some of these are given in Table IV.

TABLE IV.—TITRATION OF ZINC IN ACETATE pH 5·0 SUPPORTING SOLUTION WITH 8-HYDROXYQUINOLINE SOLUTION.
Temp. = 15 – 19°; E_A = –1·4 volt. Interval between additions, 3–5 min.

Vol. of Sample, ml	Concentrations, × 10^{-3} M		Titres, ml	
	Zinc	Reagent	Theor.	Obsd.
10	2·5	25	2·00	1·99, 2·01
10	2·5	10	5·00	5·00
10	1·0	10	2·00	1·97
1	1·75	5	0·700	0·696, 0·701
1	1·50	5	0·600	0·596

Since the solubility of zinc oxinate appeared to be higher than that of the copper complex, attempts were made to titrate copper in the presence of zinc. The results are included in Table III. At pH 6·0, although the bulk of the copper is precipitated first, pronounced co-precipitation occurs. Addition to the zinc-copper mixture of sufficient sodium potassium tartrate to render 0·07 M with respect to this substance gave better results.

Cadmium and Zinc Together

Since the noticeable rounding of the titration curves of cadmium at pH 6·0 indicated that cadmium oxinate was probably more soluble than the zinc complex, the titration of a mixed zinc—cadmium solution was attempted. Using an applied voltage of –0·9, cadmium, but neither zinc nor 8-hydroxyquinoline, is electroreducible. Under these conditions, therefore, if zinc is quantitatively precipitated first, the current should remain constant until the solution has been freed from zinc, as shown by curve I, Fig. 5. Further addition of reagent should then cause precipitation of cadmium, with the consequence that the current should progressively fall until removal of cadmium is complete, when no further change should occur. The two breaks in this theoretical titration curve would thus indicate the separate titres of the two metals. As far as the author is aware, no case of such an amperometric titration curve has been reported. On the other hand, if the cadmium comes down first, the current should decrease from the commencement of the titration, just as if the zinc were absent.

Using equimolar concentrations of the two metals, Curve II, Fig. 5 was obtained. From this it is clear that the two metals come down together. At the theoretical end point for *one* of them (viz., after 0·5 ml. of reagent has been added), the current has fallen to about half of its original value, indicating that at this point the precipitate is composed of the two metallic complexes in roughly equal proportions. Since the first portion of the curve is nearly horizontal, it would appear that zinc is in fact preferentially precipitated, but that pronounced co-precipitation then follows.

The Control of Swings in Semimicro Weighing.

Continued from page 232.

is removed with the catch, the door may be easily opened and closed by grasping the reinforced bead of the teat. To prevent its touching the moving parts, or becoming nipped in the door, the connecting tube is secured to the door frame and carried round it until near the hinge by cementing on small cork bridges, as shown in Fig. 3.

It is unwise to mount this device on the left-hand door, since the latter, then having no catch, will be blown open by repeated closing of the right-hand door during adjustment of the weights on the pan.

The Sub-micro Balance and its Applications

Part II—Technique and Applications*

By G. Ingram

A previous article described various types of fine precision balances for use in conjunction with submicro analysis. The recent development of a more robust and reliable balance allows greater application of quantitative methods. In this article some of the important techniques of quantitative analysis are described.

THE restriction of quantitative submicro analysis to simple procedures such as residue determinations and electro-deposition methods is attributed to the following causes: (1) The design and operational conditions of the earlier quartz balances allowed only the simplest of apparatus to be weighed on them as their dimensions had to be reduced to fine limits. (2) The handling of a few micrograms of material raised many difficulties and needed great skill on the part of the operator to obtain a satisfactory result.

Applications in this field also depend to a large extent on the type of material to be investigated. Quantitative methods for organic material on a scale approaching that attempted with inorganic samples are not possible for determining such elements as carbon and hydrogen. Methods for halogen, sulphur and nitrogen in simple substances should be possible using a titrimetric finish.

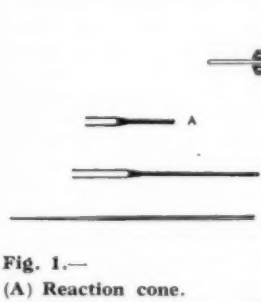


Fig. 1.—
(A) Reaction cone.
(B) Reagent capillary.
(C) Capillary pipette.

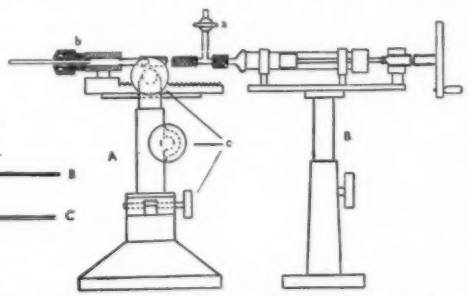


Fig. 2.—Capillary apparatus attached to micro-manipulator.
(a) Pressure release; (b) Benedetti-Pichler clamp; (c) 3-dimensional movement controls.

However, possibly larger amounts of material will be needed and considerable difficulties will have to be overcome before satisfactory methods are available.

The nature of inorganic material generally does not create manipulative hindrances as would be experienced with organic material of similar sample size. Therefore, the inorganic field is likely to advance rapidly during the next few years.

Elegant methods are already available for determining calcium[1] and nitrogen,[2] both employing a titrimetric finish.

Inorganic Technique

Treatment of a simple substance and separation of its ions is possible on the submicro scale using methods similar to those evolved for larger amounts of material. Provided a suitable balance is available, their subsequent gravimetric measurement is certain. A balance suitable for this type of work has been designed by Kirk[3] and has been described in a previous article.[4] Much of the technique involved in quantitative analysis has been adapted from that developed for qualitative analysis. The latter has been described in detail by Benedetti-Pichler.[5]

The apparatus needed for separation work is simple and easily constructed. Reactions are carried out in capillary cones (Fig. 1A) having an internal diameter 0·1–1·0 mm. and capable of containing up to 100 μg. of either solid or liquid. Reagent solutions are stored in capillary containers (Fig. 1B) which are kept ready filled in a moist chamber when an experiment is begun. Reagents are transferred from their containers with fine capillary pipettes (Fig. 1C). They are constructed by drawing out 1 mm. bore quill tubing to a suitable length and can be calibrated to deliver volumes of 0·001 ml. or less with an error below 1%.

Owing to difficulties which necessarily arise when handling the delicate apparatus and extremely small volumes of liquid, some mechanical devices have been developed which enable all operations to be carried out whilst under observation, on the stage of the microscope. The capillary apparatus is attached to micro-manipulators (Figs. 2A and 2B) and solutions are transferred from containers to reaction cones by air pressure under sensitive control. This is obtained by means of a hypodermic

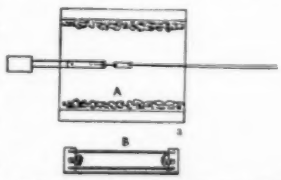


Fig. 3.—(A) Top view of moist chamber. (B) Open-end view. (a) Moist cotton.

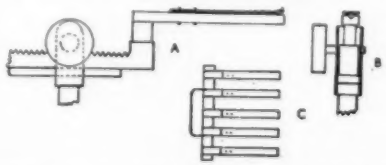


Fig. 4.—(A) Front view of reaction cone clamping device. (B) Front end. (C) Device for holding several capillaries.

* Part I appeared in *Metallurgia*, 1949, **39**, 224.

1 Kirk, P. L. and Miller, R. P., *Mikrochemie*, 1933, **14**, 15; Lindner, R. and Kirk, P. L., *Ibid.*, 1937, **22**, 291; Kirk, P. L. and Tomkins, P. C., *Ind. Eng. Chem. Anal. Ed.*, 1941, **13**, 277.

2 Kirk, P. L., *Mikrochemie*, 1934, **16**, 13.

3 Kirk, P. L., et al., *Anal. Chem.*, 1947, **19**, 427.

4 Ingram, G., *Metallurgia*, 1949, **39**, 224.

5 Benedetti-Pichler, A. A., "Micro-Technique of Inorganic Analysis," John Wiley, 1942.

syringe attached to the pipette as shown in Fig. 2B. By backward movement of the plunger air is drawn through the stopcock (*a*) or with the cock closed, liquid is drawn up into the pipette. Forward movement of the plunger expels the liquid from the pipette when the cock is closed.

Precipitates or other solids are separated from liquids by centrifuging and the liquid then removed with the capillary-syringe attachment. Evaporation of the small volumes of solution, which is very rapid on exposure to air which is not saturated with water vapour, is prevented by performing all reactions inside a moist chamber mounted on the stage of the microscope.

The moist chamber (Fig. 3) which has been designed by Cefola[6] is 68 mm. long and 60 mm. wide. A brass border frame about 5 mm. wide has two sides of metal rod 11 mm. high, provided with slots on their inner surface into which pieces of glass plate fit to form the bottom, top, and one end. The chamber is kept moist with strips of wet cotton forced into other grooves cut into the inner face of the metal sides.

6 Cefola, M., Ph.D. Thesis, New York University, 1941.

A carrier for holding the various capillaries inside the chamber consists of a strip of glass plate about 7 mm. thick. The capillaries are fixed to the surface of the glass with a layer of vaseline. In quantitative work this method of fixing is prohibited because of the danger of leaving traces of grease on previously weighed capillaries. However, by using a moist chamber open at both ends the capillaries can be held and manipulated with a special combined clamp and manipulator (Fig. 4).

Delivery of Known Volumes of a Solution

Full use is made of the microscope for delivering measured volumes of liquid. A capillary of uniform bore and known full volume is selected. With the aid of the manipulator and microscope, liquid from a reagent container is drawn up into the capillary. Measurement is effected with a micrometer eyepiece so that as little as 10^{-5} ml. of liquid can be delivered.

(*To be continued*)

Miscellaneous Microchemical Devices XX

The Control of Swings in Semimicro Weighing

By J. T. Stock and M. A. Fill

ALTHOUGH the makers may not claim a sensitivity greater than 0·1 mg., a good analytical balance which has been well cared for may often be used to estimate mass to the nearest 0·01 to 0·02 mg., and is therefore suitable for semimicro quantitative analysis.[1] In order to achieve the maximum sensitivity, the method of swings must be used. Although the skilful release of the arrestment will often produce oscillations of the desired magnitude, a means for adjusting the amplitude of the swings is useful.

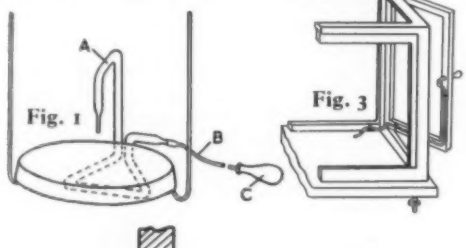


Fig. 1

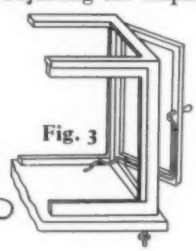


Fig. 3

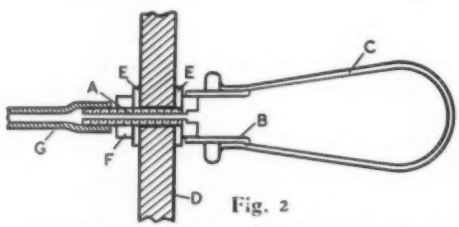


Fig. 2

Fig. 1.—Simple arrangement for the control of swings.
Fig. 2.—Attachment for door of balance.
Fig. 3.—Arrangement of connecting tube.

Various electromagnetic devices may be used for this purpose, or, more simply, the air jet attachment shown in Fig. 1. Jet assembly A is of heavy-walled glass tubing and is secured to the floor of the balance case by a smear of cement or by three narrow strips of adhesive cellulose tape. The jet, which is of about 1 mm. bore, is arranged about 1 cm. inwards from the edge of the right-hand pan and to point vertically downwards. While not allowing the jet to strike the pan when the latter is in its most elevated position, the jet should be as close to the upper surface of the pan as possible. The other end of A is tapered to permit attachment of the cycle valve rubber connecting tube B. Air impulses are provided by an ordinary teat-pipette (fountain pen filler) C, attached to the other end of B. Normally kept inside the balance case, the teat-pipette is placed on the bench in front of the balance when the latter is to be used. (Provided that the sash is lowered gently, the constriction of the connecting tube is not sufficient to stop the flow of air.)

In completing a weighing, the arrestment is very slowly released. Two or three light puffs of air, obtained by sharply pressing the teat on the bench top, then enable the amplitude of the swings to be increased to the desired extent. If the swing is initially too great, it may be rapidly reduced by administering a puff of air *opposing* the direction of motion of the pan, as the pointer passes the central scale division.

An assembly more suitable for constant use may be made by replacing the teat-pipette by the attachment shown in Fig. 2. No permanent alteration is required, so that the balance may be restored to its original form in a few minutes. A brass cheesehead screw forms the stem A, and has a $\frac{1}{16}$ in. diameter hole drilled right through lengthwise. A short length of copper tubing B is sweated on to the head of the screw as shown. The outer end of B is lightly flared to retain rubber teat C. By removing the catch of the right hand door, the attachment may be mounted in the hole thus left free in door frame D, using washers EE and nut F as shown. The end of the connecting tube G is forced on to the projecting shank of the screw. Although the door knob

Continued on page 230.

1 Belcher, R., and Godbert, A. L., "Semi-Micro Quantitative Organic Analysis," Longmans, London, 1945, p. 10.

Molybdenum-bearing Stainless Casting Alloy Has Wide Range of Uses

By Norman S. Mott

THE 18-8 chromium-nickel alloy with additions of 2 to 3% of molybdenum is receiving ever wider use in industry because of its unique and useful properties. It is estimated that about a third of the stainless steel casting industry's current 18–8 steel output is of this type. The molybdenum-bearing chromium-nickel alloy is a modification of the conventional low carbon 18% chromium –8% nickel alloy, so commonly used in the corrosion resisting field for many years. The addition of molybdenum tends to enhance corrosion resistance and to raise the strength at elevated temperatures. Molybdenum increased its passivity under mildly oxidising corrosion conditions, improves its inherent corrosion resistance in reducing media, lowers its susceptibility to intergranular corrosion after critical heating, such as would result from a welding operation, and produces practical immunity to the pitting type of corrosion caused by sea water and chloride chemicals.

Passivity, a surface characteristic of nobility and low corrosion rate, is maintained with a 2% and upwards addition of molybdenum under many practical corrosion conditions; however, when the molybdenum content exceeds about 3%, an excessive rate of corrosion results in the boiling 65% nitric acid test commonly used for 18:8 type alloy acceptance. Therefore, 3% is taken as the maximum in most specifications.

Molybdenum additions of 2 to 3% are also quite effective in reducing susceptibility to the intergranular type of corrosion, being about as potent in this respect as niobium additions in its usual amount (e.g., 8 x % C). In a great variety of corrosive media, this obviates the necessity of heat treatment, after welding operations; however, in the sensitised condition, the general corrosion resistance to boiling 65% nitric acid is low. Thus, this alloy is not recommended for quench annealing heat treatment use in hot nitric acid unless a quench anneal heat treatment is given after welding operations.

The pitting type of corrosion in stainless steels is caused above all by the halides and their wet salts, or salt solutions. Molybdenum additions are of special value in avoiding this form of corrosion.

The molybdenum-bearing 18-8 alloys have high resistance to stress corrosion cracking; in this case, however, higher molybdenum percentages of 3 to 4% are better, and a stress relieving anneal at 870° C. improves resistance. Hot solutions of acidulated chlorides, especially zinc and magnesium, are the worst offenders in this form of corrosion failure.

Molybdenum in itself rates high in corrosion resistance, and its inclusion in the 18–8 stainless steels imparts added resistance to many corrosive media. Additions give improved resistance in the following environments: Organic acids or their vapours, especially when hot; cold and hot solutions of sulphuric acid; phosphoric acid when concentrated and hot; fatty acids at elevated temperatures; solutions or vapours containing small percentages of chlorine, hydrochloric acid or other halogens and their acids; hot solutions of chlorides; acid salts or neutral salts, accompanied by a small percentage of acid; sulphurous acid solutions at high temperatures and pressures, or where small amounts of sulphuric acid may be present due to oxidation, as in the sulphite pulp processing liquors; hot strong caustic solutions; and oxidising alkaline or acid salts.

Some notable uses of the molybdenum-bearing 18-8 stainless steel referred to include: Paper pulp digester fittings; film developing parts; mine pumps handling erosive acid waters; handling products of combustion containing sulphur dioxide in the cooler sections of the system where condensation and severe corrosion may occur; for pumps in the petroleum industry where brine is associated with crude oil; high temperature corrosive valve service; for handling flavouring sauces or brines for pickles; equipment for handling corrosive bleaches or acid dyeing baths; handling nitrating acids for explosives; handling ammonia-sodium chloride liquors in the ammonia soda process; handling chlorinated solvents when moisture is present; manufacturing boric acid These show its versatility in a wide range of corrosive applications.

From *Materials and Methods*, **30**, 1949, 50–53.

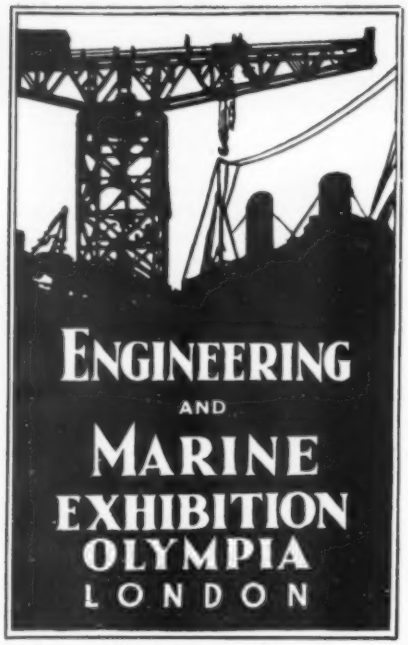
Cold Solder

SOLDERS made from powdered aluminium may replace the older-type solders which had to be melted and "flowed in" to dents and other damaged areas of automobile bodies. The new solders are said to require no heat and thus avoid damaging adjacent painted surfaces. Several successive applications can be employed to build up thicknesses as much as one inch. The Reynolds Metals Company, Louisville, has aided the development of these materials and is now supplying large quantities of aluminium powder to concerns making the new-type solders which are now available.

These "cold" solders are doughlike, about the consistency of plastic wood. When applied by spatula or wiper, the solvent evaporates and the metal mass soon hardens sufficiently to be filed or sanded. It adheres strongly to a properly cleaned surface. When sanded smooth it provides an excellent base for paint, enamel, or lacquer coatings.

A wide variety of applications for these solders are being studied. One of the most important applications already extensively explored is the repair of automobile bodies and fenders. Repairing dents or holes in thin sheet forming motor car bodies and fenders may be

From *Mech. Eng.*, 1949, **71**, 419.



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both difficult and expensive when attempting to do the work by conventional soldering or welding methods. However, use of the new cold solders is claimed to be exceptionally easy and effective.

Applying the material is simple. First, the area surrounding the hole or dent must be cleaned thoroughly. Sanding or buffing is recommended. The composition is then applied as desired to build up the damaged part. It is not necessary to pay particular attention to getting a smooth surface when applying the material, although the smoother the surface the easier it will be to obtain the final smooth surface desired.

After a period ranging from 20 to 30 min. for thin coatings, the composition will have become hardened. Any surplus material can then be easily removed by use of a file or sandpaper. Sanding and buffing to a smooth surface for painting is greatly facilitated because the composition looks and acts just like metal once it has set. It blends into the surrounding metal without cracking around the edges. It will even withstand a slight amount of bending without breaking.

Effect of Boron on the Structure and some Physical Properties of Plain Cast Irons

By Alexander I. Krynitsky and Harry Stern

THE effects of boron additions, ranging from 0·001 to 0·48%, on the properties of various grey cast irons have been determined by casting chilled plates, wedge castings, and arbitration bars. Nine different irons were used, the composition of which are given in Table I. These irons were remelted and boron in amounts up to 0·48% was added.

The solidification characteristics of the various irons so treated were determined by making "inverse rate" cooling curves. The data produced indicate that the undercooling effect increased with an increase in boron content. It is noteworthy that the temperature differential between the first and second recalescence reactions becomes smaller as the boron is increased, until the cooling curve of a boron-treated iron containing 0·33% of boron showed only one such reaction. These results indicate that as the boron content increases in a given iron, the composition approaches the eutectic where the apparent liquidus and solidus are merged into one reaction of heat evolution.

TABLE I.

Composition of basic pig irons used in preparing heats with different boron contents.

Total C	Si	Mn	P	S	Ti	B
%	%	%	%	%	%	%
3·79	1·40	0·63	0·181	0·062	0·029	0·006
3·44	2·43	0·77	0·395	0·05	0·055	0·007
3·56	1·71	0·74	0·553	0·038	0·088	0·001
3·80	1·66	0·70	0·54	0·034	0·100	0·002
4·14	1·48	0·64	0·05	0·022	0·075	0·001
3·51	2·85	0·49	0·80	0·032	0·105	0·003
3·61	2·66	0·68	0·78	0·045	0·12	0·005
3·31	2·29	0·50	0·54	0·025	0·09	0·005
3·55	2·73	0·24	0·82	0·021	0·022	0·001

Microscopic examinations were conducted on specimens cut from the transverse bars and the chill-test plates. Typical structures show that as the boron content increased, the amount of graphite increased, and the graphite flakes were reduced in size. The structure of the irons without boron addition consisted essentially of pearlite and ferrite, whereas those of the irons containing 0·085 and 0·17% of boron consisted principally of pearlite and carbides. With a further increase in boron (0·29%) the structure consisted of islands of pearlite and cementite. Some of these islands contained pearlite surrounded by an envelope, whereas others showed only traces of pearlite. No microstructural differences in the appearance of carbides in boron-treated and untreated irons were detected, although the cementite of boron-containing iron is thought to be of a complex nature.

The depth of chill, determined on plate and wedge specimens, was taken as a criterion of the susceptibility to chill of the different irons. All the irons were made from the same stock and under similar melting and pouring conditions. Investigation showed a pronounced increase in the depth of chill with an increase in the boron content. Fractures of plates containing 0·32–0·35% of boron are white and mottled, whereas those containing 0·37–0·48% of boron are wholly white.

Vickers hardness determinations were made on clear chill portions of the chill plate specimens, by using a 50 kg. load, and it is shown that, in general, an increase in the Vickers number accompanies an increase in boron content. The relationship was particularly significant for the irons containing 0·35–0·48% of boron. It is noteworthy that the Vickers hardness number of the chill cast plate containing 0·48% of boron was approximately 720—equivalent to approximately 620–650 Brinell—which is considerably higher than that value for ordinary white irons whose Brinell numbers range from 320–530.

From Jour. of Research, U.S. Bureau of Standards, **42**, No. 5, 465–469.

Heating of Objects in Furnaces

By V. Vondras

THE process of heating solid objects of various shapes in furnaces is mathematically analysed. General solution of the basic differential equations defining the temperature characteristics throughout the cross-section of the heated object is a lengthy process and for practical purposes it is sufficient to determine the temperatures on the surfaces and at the centre of the heated object.

These temperatures can be calculated by means of simplified equations or graphs. For a furnace of constant temperature the temperatures on the surface and at the centre t_{ss} of the heated object, and also its mean temperature can be expressed by an exponential function, e.g.: t_{ss} (°C.) $=$

$$t_f - (t_f - t_o)\,[\rho - (\rho - 1)\kappa]e^{-\frac{a\,\kappa}{X\,\gamma\,c}\tau}$$

where t_f and t_o are the temperature of the furnace and the initial temperature of the object respectively; the values for κ are obtained from curves which are presented, and $\rho = 1{\cdot}5$, $2{\cdot}0$, and $2{\cdot}5$, depending on the shape of the object, a is the coefficient of heat transfer from furnace atmosphere to surface of object, γ is the specific gravity of the object, c is its specific heat, and X is its volume divided by the surface area. The time required to heat a part to a required temperature can be calculated by the equation:

$$\tau\ (\text{hours}) = \frac{X\,\gamma\,c}{a\kappa}\log\frac{t - t_o}{t_f - t_o}$$

where t is the final temperature of the object. Equations are also given

From *Strojnícky Obzor*, 1947, **27**, June, pp. 245–250, July, 280–282. [In Czech]. Reproduced from *Jour. I.S.I.*, June, 1949.

for furnaces with a constant heat input. For materials where the specific heat and the coefficient of heat transfer vary with the temperature, the calculation is made in several temperature ranges and in each range these values are assumed to be constant. Heating with a constant supply of heat has the disadvantage that, throughout the process, the difference between the temperatures of furnace and part is always considerable, thus causing internal stresses. With steel it is best to increase the heat input gradually, attaining a maximum input at the highest temperature of the part and to decrease the input gradually towards the end of the holding time. Sufficient time must be allowed to permit the part to be heated right through. The furnace temperature should not greatly exceed the desired temperature of the part, as this causes the temperature of the core to be too low when the surface reaches the desired temperature. According to Trinks 160 kg. of steel/hr./sq. m. can be heated to the hardening temperature in a gas furnace and 315 kg. to the annealing temperature. In an electric furnace with an input of 30 kw./sq. m. 280 kg. can be heated per hour to 1,000° C. The time for heating in a gas-fired muffle furnace from 20° to 400-1,200° C. is given by :

$$\tau \text{ (min)} = 500\,\frac{D - 10}{t - 200}$$

where D is the diameter (mm.) of the heated bar and t is the final temperature which is approximately equal to the furnace temperature. In a lead bath the time for heating from 200° to 500-900° C. is

$$\tau \text{ (min)} = 0{\cdot}114D + 0{\cdot}00008Dt.$$

In a salt bath the time for heating from 400° to 550-750° C. is given by :

$$\tau \text{ (min)} = 110[D/(t - 200)].$$

In a salt bath fitted with electrodes the time for heating from 850° to 1,000-1,300° C. is $\tau \text{ (min)} = 0{\cdot}50D - 0{\cdot}00013(D - 15)t$. In an oil bath the time from 20° to 120–260° C. is :

$$\tau \text{ (min)} = 290(D - 20)/(t - 100),$$

Data are also presented for larger objects and for the holding times at various desired temperatures.

Molybdenum Disulphide as a Lubricant*

IN a recent report by Johnson, Godfrey and Bisson[1] excerpts are given from work by Johnson, Swikert, and Bisson[2] on the friction of solid films on steel at high sliding velocities, in which the coefficient of kinetic friction and the wear characteristics of steel specimens so treated as to have solid chemical films that are predominantly of the materials desired were determined by experiments. Friction measurements in the experiments were made by means of an apparatus which consisted basically of an elastically restrained spherical rider sliding on a rotating disc.

Uncontrolled variables, such as wear of the rider, natural frequency of the restraining assembly and variations induced by the driving mechanism, had no appreciable effect on accuracy of the data obtained. In all but isolated cases the margin of error in the coefficient of friction was within $\pm 0{\cdot}02$ of the values given.

Several chemically and thermally stable materials are available which might be effective in reducing friction and wear under extreme conditions. Two of the best examples of these film-forming lubricants are molybdenum disulphide and graphitic carbon. These materials are similar in that both have laminar structures Molybdenum disulphide has been used as a die lubricant in the forging of metal parts and as a bearing lubricant for a rotating anode X-ray tube. Graphite is a more commonly used lubricant and has been employed in numerous applications. The experimental investigation under discussion concerned solid films produced by these two materials.

Data showing the effectiveness of molybdenum di-sulphide and graphite as solid-film lubricants at high sliding velocities are given and it is noteworthy that the use of molybdenum disulphide produces a trend toward progressively lower values of friction as sliding velocities are increased and, under the conditions reported, reduces friction more than the use of graphite. It is shown that at high sliding velocities, molybdenum di-sulphide is nearly as effective in reducing friction as one of the best polar-type boundary lubricants, oleic acid.

Molybdenum disulphide is stable at high temperatures (melting point 1,185° C.) and pressures[3]. Each lamina of this compound is composed of a sheet of molybdenum atoms with a sheet of sulphur atoms on each side. One of these laminæ adheres strongly to the iron surface because of a strong metal-sulphur bond. The other laminæ slip easily because of the weakness of the sulphur-sulphur bond.

The tenacity of molybdenum disulphide as a film material was demonstrated by the continuous run of the rider without radial traverse on the film using a 269-gram load with a sliding velocity of 4,000 ft./min. over a period of 30 minutes. Stable but slightly increasing friction values were observed. The slight film failure that occurred was not serious enough to allow welding to take place between the sliding surfaces. In another experiment, a rider with a contacting area such as to give an apparent loading of 3,000 lb./sq. in. was allowed to slide on a continuous track at a velocity of 4,000 ft./min. for a period of over 2 hours there was little change in friction and no sign of failure of either the steel or molybdenum-di-sulphide film to the steel base at any location during this experiment.

Another investigation concerned with the friction properties of various special lubricants under high pressure is reported by Boyd and Robertson[3] who used a method suggested by M. D. Hersey and based upon work done by Bridgman[4]. A large number of lubricants were tested by this method, which could be classified in the following groups: mineral, animal and vegetable oils; mineral oil plus various additives; fatty acid additives; greases; and solid lubricants.

Test results show that the shearing stresses increased gradually with angular displacement for all of the oils. The coefficients of friction differed considerably, however, and the effect of pressure was appreciable. There was also a tendency for the coefficients of friction of the mineral oils to decrease slightly with increased pressure, while the coefficients for the fixed oils had a tendency to rise under the same condition.

Tungsten di-sulphide and molybdenum di-sulphide possessed very good shearing characteristics. The average coefficients of friction were lower for these than for any of the other solid lubricants tested. Very low coefficients obtained for molybdenum di-sulphide explain the numerous applications to which it has recently been adapted.

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* From *Alloy Metal Review*, March, 1949.

1 Johnson, Robert L., Godfrey, Douglas, and Bisson, Edmund E.; Tech. Note No. 1578, published by Nat. Advisory Comm. for Aeronaut., Washington, D.C., April, 1948.

2 Johnson, Robert L., Swikert, Max A., and Bisson, Edmund E.; Tech. Note No. 1442, Washington, D.C., 1947.

3 Boyd, John, and Robertson, B. P.: *Trans. A.S.M.E.*, 1945, 67, pp. 51–56.

4 Bridgman, P. W., "Shearing Phenomena at High Pressures, Particularly in Inorganic Compounds," *Proc. Am. Acad. Arts. and Sc.*, 1937, 71, 387–460.

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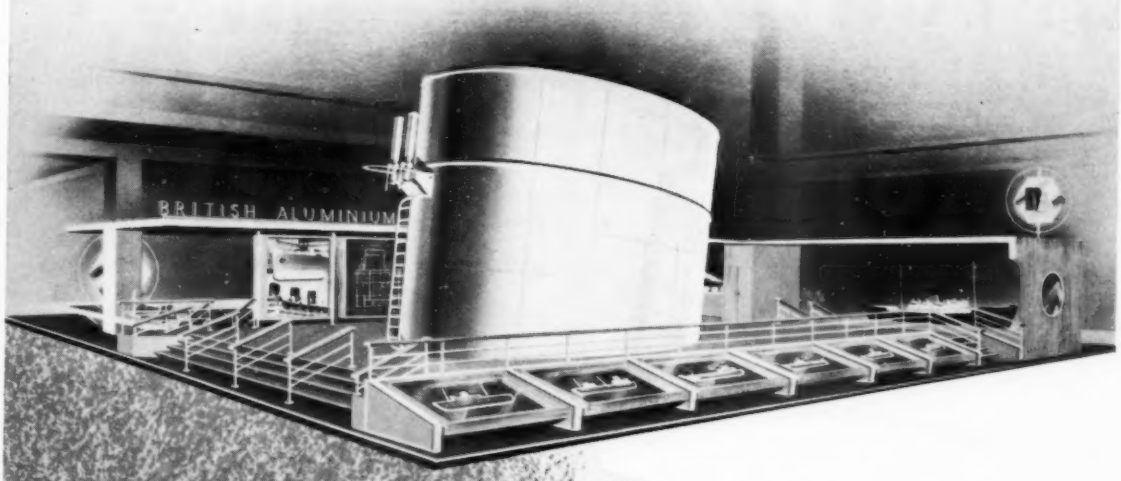

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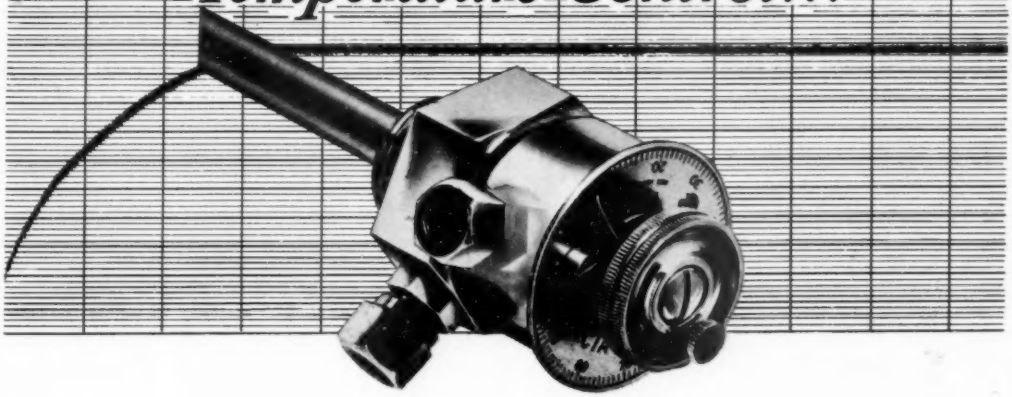

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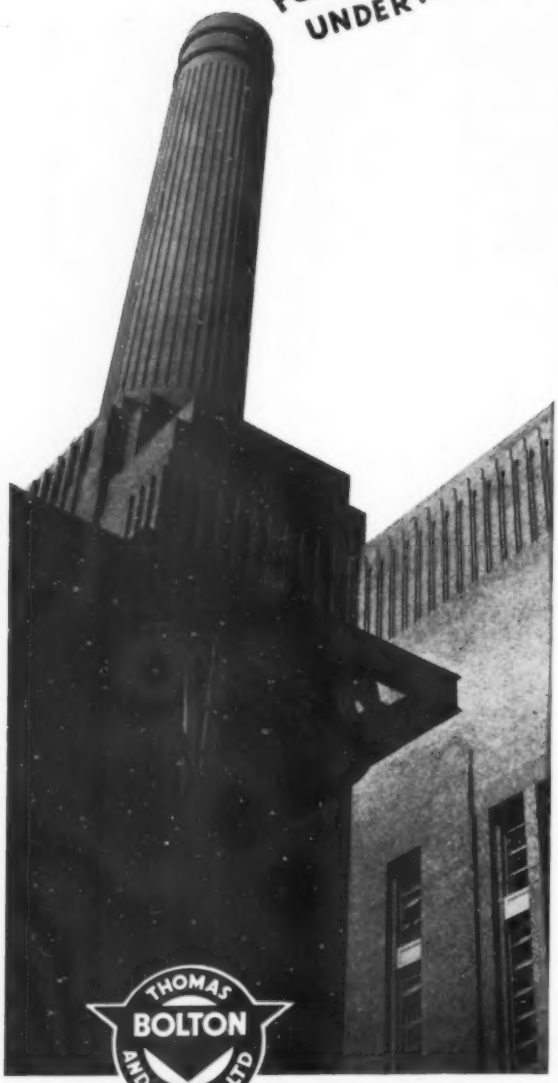

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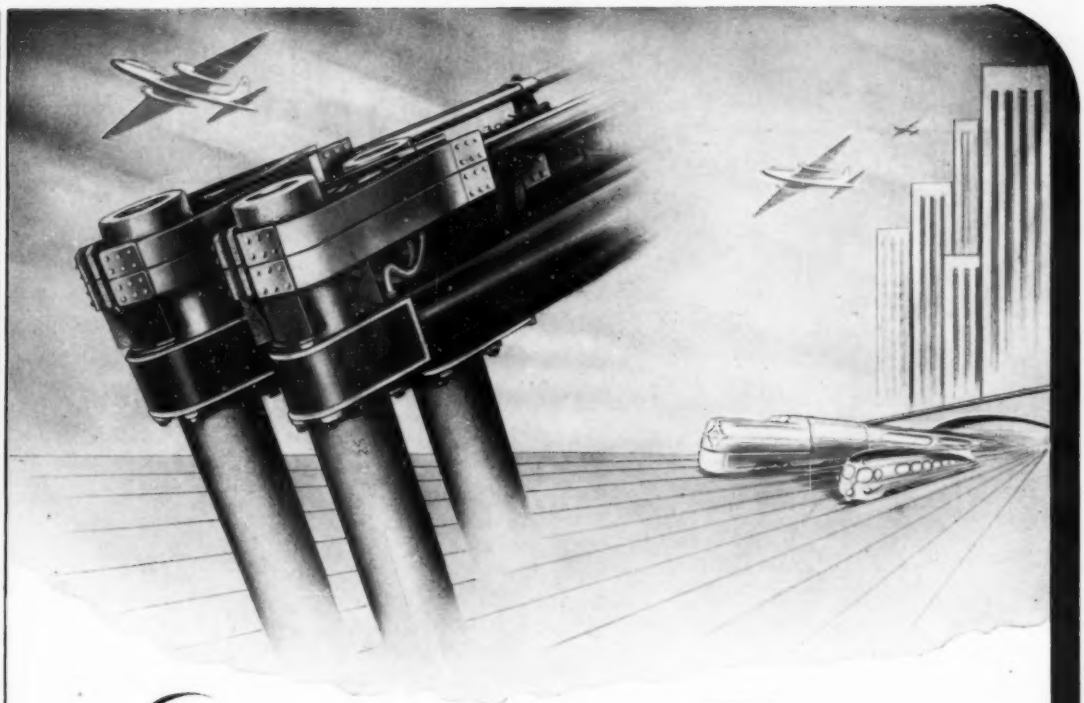

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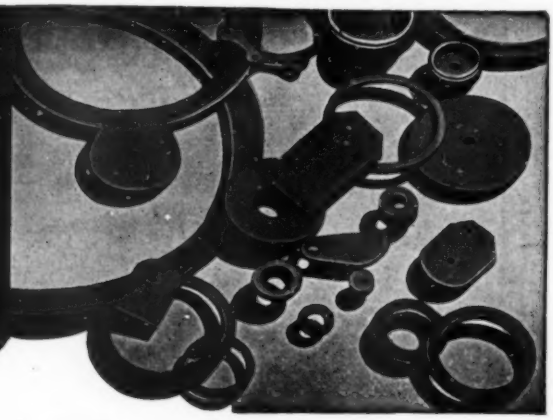

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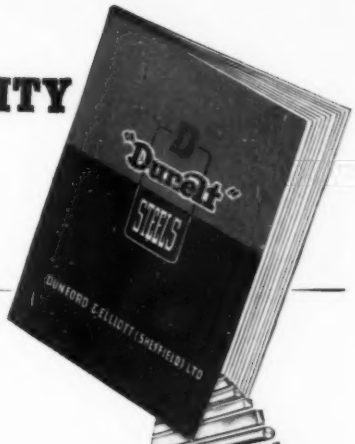

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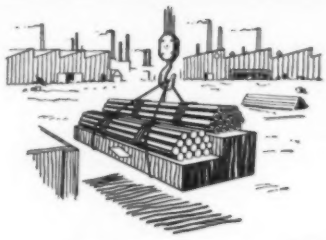

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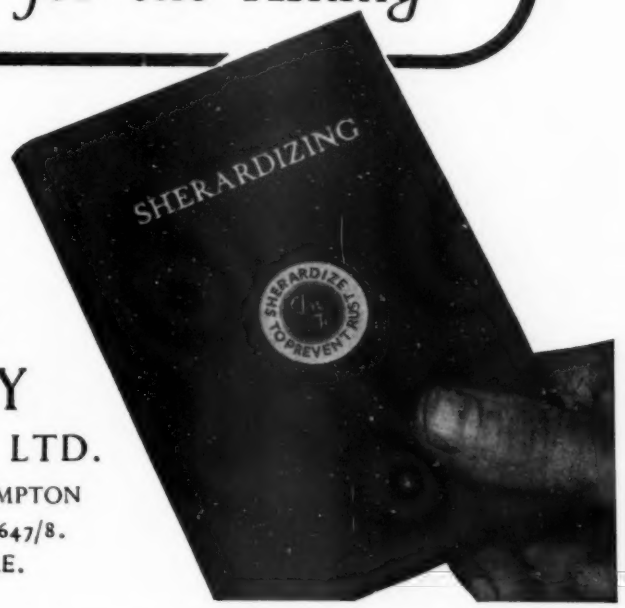

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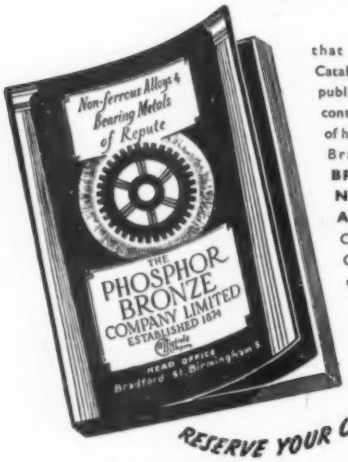
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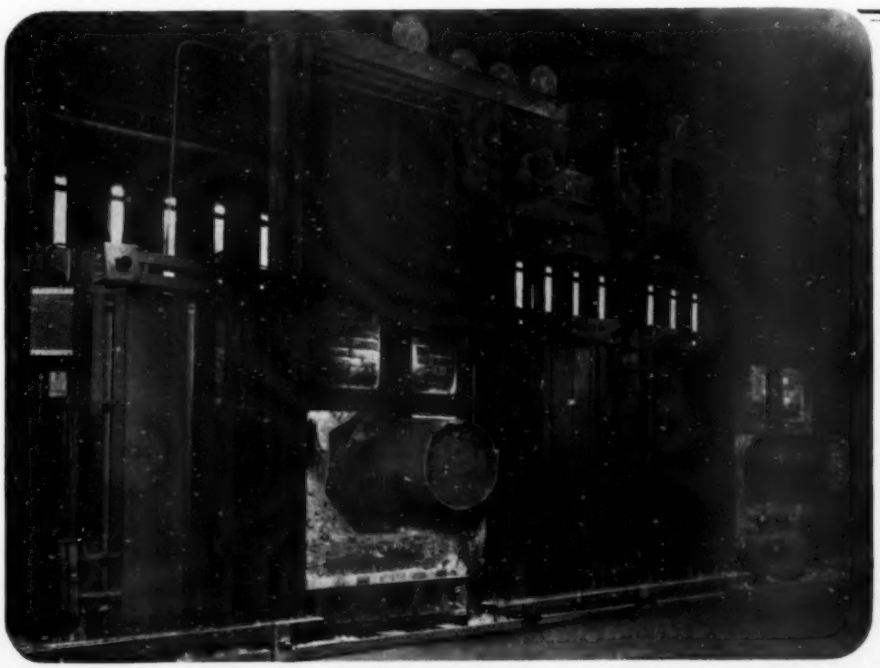

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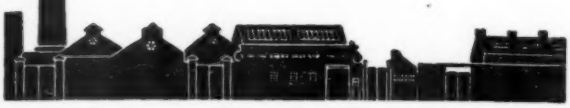

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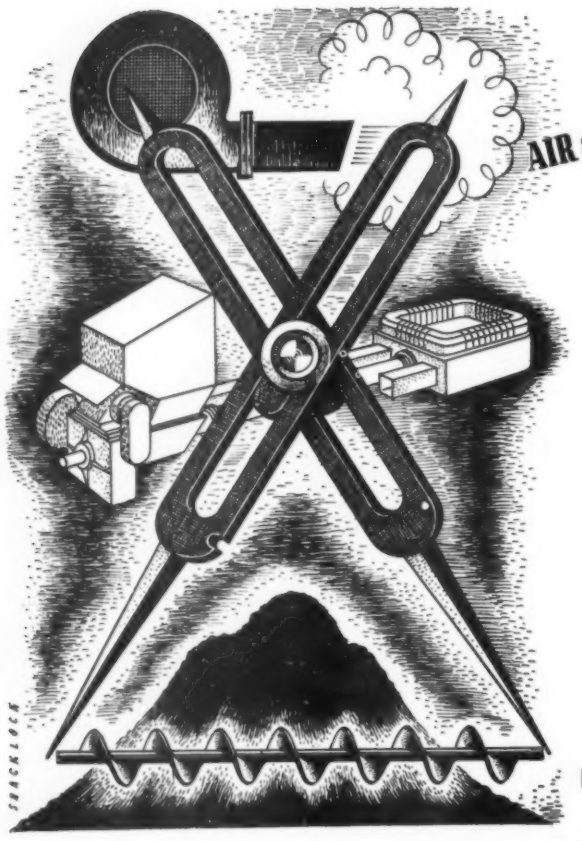

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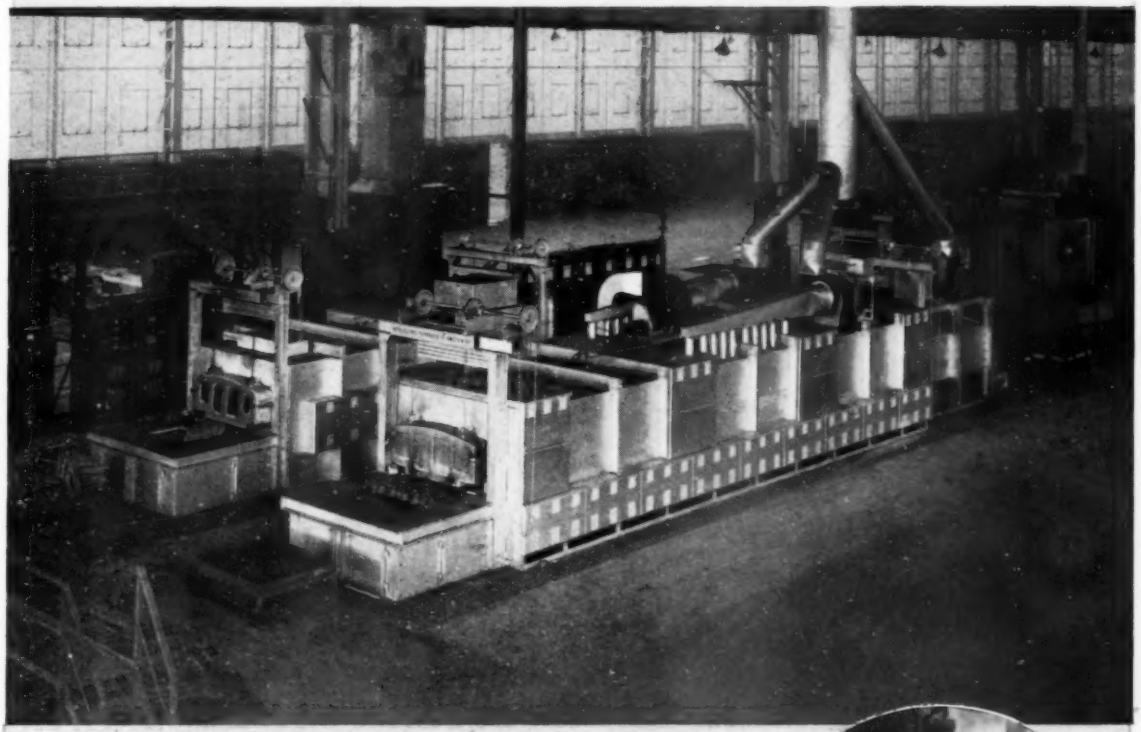
Index to Advertisers

	PAGE
Airmec Laboratories, Ltd.	6
Association of Light Alloy Refiners	55
Andrews, Thos., & Co., Ltd.	44a
Armstrong Whitworth & Co., Ltd.	20
Bigwood, Joshua	60
Birkett, T. M., & Sons, Ltd.	48
Birlec, Ltd.	28
Bolton, Thos., & Sons, Ltd.	48
Brayshaw Furnaces & Tools, Ltd.	24
British Acheson Electrodes, Ltd.	49
British Aluminium Co., Ltd.	45
British Driver Harris Co., Ltd.	57
British Electro-Metallurgical Co., Ltd.	46
British Iron & Steel Federation	51
British Oxygen Co., Ltd.	21
British Thomson-Houston Co., Ltd.	34
Clifford, Chas., & Son, Ltd.	54
Climax Molybdenum, Ltd.	38
Copper Development Association	52
Davey & United Engineering Co., Ltd.	4
De La Rue Gas Development, Ltd.	47
Dowson & Mason Gas Plant Co., Ltd.	57
Dunford & Elliott (Sheffield), Ltd.	53
Durrans, James, & Sons, Ltd.	32
Electroflo Meters Co., Ltd.	17
Electromagnets, Ltd.	56
Emery Bros., Ltd.	58
Ether, Ltd.	52
Expert Tool & Case-hardening Co., Ltd.	50
Engineering & Marine Exhibition	44a
General Electrical Co., Ltd.	33
General Metallurgical & Chemical Co., Ltd.	54
General Refractories, Ltd.	22
Gibbons Bros., Ltd.	Back Cover
Grundy, B., & Co., Ltd.	58
Hale & Hale, Ltd.	Front Cover
Halesowen Steel Co., Ltd.	Inside Front Cover
Hallamshire Steel & File Co., Ltd.	11
Harper, John, & Co., Ltd.	40
High Duty Alloys, Ltd.	5
Hughes, F. A., & Co., Ltd.	25
I.C.I., Ltd. (Cassel)	23
Incandescent Heat Co., Ltd.	Inside Back Cover
Integra Co., Ltd.	42
J.L.S. Engineering Co., Ltd.	30
Kasenit, Ltd.	19
Keeton, Sons & Co., Ltd.	58
Kingscliffe Insulating Products, Ltd.	13
Loewy Engineering Co., Ltd.	29
Manganese Bronze & Brass Co., Ltd.	41
Marshall, Thomas, & Co., Ltd.	8
McKechnie, Bros., Ltd.	46
Metropolitan Leather Co., Ltd.	50
Mond Nickel Co., Ltd.	10
Morgan Crucible Co., Ltd.	37
Nitralloy, Ltd.	58
Phosphor Bronze Co., Ltd.	56
Priestman, T. J., Ltd.	36
Priest Furnaces, Ltd.	3
Renfrew Foundries, Ltd.	15
Rockweld, Ltd.	31
Royce Electric Furnaces, Ltd.	9
Rozalex, Ltd.	56
Sanderson Bros. & Newbould, Ltd.	14
Slough Metals, Ltd.	58
Smethwick Drop-Forgings, Ltd.	35
Stein, J. G., Ltd.	27
Sterling Metals, Ltd.	12
Sternol, Ltd.	44a
Thermal Syndicate, Ltd.	Inside Front Cover
Thermic Equipment & Engineering Co., Ltd.	26
T.I. Aluminium, Ltd.	18
Universal Aluminium Co., Ltd.	58
Universal Engineering Co.	56
Ward, Thos. W., Ltd.	16
Wellman Smith Owen Engineering Corp., Ltd.	44
Wiggin, Henry, & Co., Ltd.	7
Wincott, G. P., Ltd.	39
Zinc Alloy Rust-Proofing Co., Ltd.	55

Continuous

HEAT TREATMENT PLANT FOR FORGINGS



Illustrated above is a general view of the complete electrically-heated, continuous heat-treatment plant for forgings, installed at the Bromsgrove works of Messrs. John Garrington & Sons, Ltd.

The plant consists of the following units :—

A Continuous Normalising and Annealing furnace ; a Continuous Hardening furnace with oil quench tank, oil cooler, circulating pumps and discharge conveyor ; a Continuous Tempering and Normalising furnace.

The Hardening furnace discharges direct into the oil quench tank and components are automatically removed by the continuous discharge conveyor. This installation, the largest of its type in Europe, deals with 3 tons of forgings per hour, and has a total connected rating of 1,300 kW.

Each furnace conveyor is of the cast nickel-chromium link-belt type, as shown inset. Combining lightness of construction with high strength and maximum flexibility, the belt forms a flat hearth on to which small or large forgings may be directly loaded.

The plant is one of many types designed by Metalectric to meet specific requirements.

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